ELEMENTS OF AGRICULTURE

A TEXT-BOOK PREPARED UNDER THE AUTHORITY OF THE ROYAL AGRICULTURAL SOCIETY OF ENGLAND

BY THE LATE

W. FREAM, LL.D.

TWELFTH EDITION
(NINETIETH THOUSAND)

EDITED BY

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PREFACE

TO THE

TWELFTH EDITION.

THIS book is the lineal descendant of "Fream's Elements of Agriculture," which was first edited and for the most part written by the late Dr. Wm. Fream at the request of the Royal Agricultural Society of England. In this form it ran through seven editions.

The eighth edition, edited by Professor J. R. Ainsworth-Davis in July, 1911, and three subsequent editions, being exhausted, the R.A.S.E. entrusted the preparation of a twelfth edition to the staff of the Cambridge School of Agriculture.

After much consideration it was decided that so great a change had taken place in agricultural science and in the outlook of agriculturists on that subject that the whole scheme of the book should be revised and the book substantially re-written. The scheme adopted was to allocate each subject to the appropriate member of the staff with the instructions that he should include in his section or sections those aspects of his subject which, in his judgment, are necessary for the instruction of readers, including in the first place students at agricultural colleges and schools, and in the second place farmers who wish to gain an all-round general knowledge of agricultural science.

Each writer has attempted (i) to expound his section in the form of a readable story, giving references to more advanced books from which the reader can fill in the detail of any parts of the work in which he wishes to specialize, (ii) to give cross references to other sections of the book, so as to make the various parts hang together, and (iii) to show the bearing, in the case of the more scientific sections, on agricultural practice.

The whole of the MS. has been revised and correlated by the writers in committee, and finally edited by Professor Sir Rowland Biffen, who took over this task on the death of Professor T. B Wood. The R.A.S.E. is deeply indebted to Sir Rowland Biffen and to all those members of the Cambridge School of Agriculture who have assisted him, viz. :— A. Amos M.A., R. H. Biffen, M.A., F.R.S., D. Boyes, M.A., H. R. Davidson, M.A., F. L. Engledow, M.A., F. H. Garner, M.A., R. E. Glover, B.Sc., M.R.C.V.S., E. T. Halnan, M.A., J. Hammond, M.A., H. Hunter, M.A., D.Sc., W. S. Mansfield M.A., F. H. A. Marshall, Sc.D., F.R.S., H. H. Nicholson M.A., F. Procter, M.A., H. G. Sanders, Ph.D., C. Warburton, M.A., A. E. Watkins, M.A., H. E. Woodman, M.A., Ph.D., D.Sc

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EXTRACTS FROM THE PREFACE TO THE FIRST EDITION.

THE preparation of this Text-Book was undertaken by the Royal Agricultural Society of England, in compliance with the many demands that had been addressed to it for an elementary work on Agriculture adapted for use in rural and other schools and classes.

The general scheme of the work was settled by a Sub-Committee appointed by the Council of the Society, and consisting of Lord Moreton (Chairman), Major Craigie, Mr. C. De L. Faunce De Laune, Mr. D. Pidgeon, Mr. Martin J. Sutton, and Mr. Charles Whitehead.

The Sub-Committee placed the preparation of the Text-Book in the capable hands of Dr. W. Fream, to whose skill and knowledge of the subject any success which the work may attain will be chiefly due.

The Sub-Committee desire also to record their grateful acknowledgments, for valuable suggestions and revision of the proof-sheets, to Sir John Lawes, Bart., Sir John Thorold, Bart., Sir Jacob Wilson, Mr. Alfred Ashworth, Mr. Thomas Bell, Mr. J. Bowen-Jones, Mr. Chandos-Pole-Gell, Dr. J. H. Gilbert, Miss E. A. Ormerod, Mr. D. Pidgeon, Mr. Clare Sewell Read, and Dr. Voelcker.

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ELEMENTS OF AGRICULTURE.

CHAPTER I.

THE FORMATION, DISTRIBUTION, CLASSIFICATION AND PROPERTIES OF SOILS.

To the farmer, the soil is both a site for his " factory " and an important part of his raw materials. Most of the varied systems of farming aim at converting this raw material into saleable commodities. These may be either vegetable or animal foodstuffs. The investigation of the problems of the soil and of plant growth has, since earliest times, attracted the attention of scientists, so that to-day we possess a great accumulation of experimental data, derived both from field trials and laboratory experiments, bearing on the subject from all possible angles. The number of workers engaged upon the subject is nowadays very large, as is also that of the educationists who pass on the results of their labours to the practical man. Each year sees new additions to our knowledge, so that the phenomena of soils and their connection with the growth of the herbage upon them now constitute a science in itself.

The history of soil science until fairly recent years, and especially in this country, has been largely a record of attacks on the problems connected with the soil by practitioners of various established sciences such as chemistry, physics, geology, zoology and bacteriology ; all of which have made their contributions to knowledge in this subject and have enabled notable advances to be made. Of late years, and particularly as a result of the lead given by Russian soil scientists, the subject has tended to develop as a special branch of knowledge, now dignified in some quarters by the name Pedology.

Geological and Soil Maps.—These workers have devoted much time and energy to the classification of soils, and soil maps of various parts of the world have been produced. From the soil map of Europe the lay observer would generally glean two impressions. The first is the sequence of soil belts running across Russia from the south-west to the north-east, coinciding with areas over which uniform climatic conditions obtain. The second is that on this map the British Isles are credited with only three types of soil, a state of affairs which would appear to be absurd to local observers and would leave them curious as to the basis of classification. A moment's thought, however, shows that this particular delineation may be justified ; and, indeed, the main dividing line is seen to separate the country into the comparatively humid north

and west on the one hand, as against the drier south and east on the other. But when consideration is given to matters such as the colour of the soils, their texture and their chemical composition, it becomes apparent that for practical purposes a much more detailed map of the soils of these islands is both desirable and possible. In point of fact, the Drift Map of the Geological Survey is at present the most useful for this purpose, and especially in the south and east it delineates the surface of the country from a soil point of view very effectively. It can, therefore, be concluded that to a certain extent there is a connection between the geology of any area and the properties of its soils. This is nearly always the case from the local and practical point of view. It is when one is studying the soils of the world as a whole that the considerations on which the soil map of a continent is based become apparent, assume their real importance, and show a systematic arrangement. It is not then so surprising that the processes which culminate in the development of a particular type of soil have, in some countries, gone on so long as to produce a definite uniform soil covering over several different geological formations. Nor is it so surprising to find that the main types of soil and their sequence across the country, as they occur in Russia, have their counterparts both individually and in the same general sequence in other large continental areas, as, for instance, in North America.

But in the comparatively small area of the British Isles, the geological factor, with its variations, probably produces the greatest diversities in soil types. The Geological Survey publishes two types of maps, one which is known as the Solid Edition, mapping the make-up of the earth's crust as it would appear if subjected to a process of cleaning-up on the large scale, *i.e.*, if all soil and surface deposits were removed, and a second described as the Drift Edition, which maps the surface as it exists, including all surface deposits. If the Solid and Drift sheets for any locality be compared, the significance of the two will be better seen. It may be as is frequently the case, that the former will show a large and varied succession of strata which in the latter are mostly covered by a surface layer of peat, gravel or boulder clay. Or it may happen, as in some areas of the south-eastern parts of the country, that there is not so much difference between the two maps, except for limited areas of superincumbent gravel, clay or alluvium. Whichever is the case, it can be seen that the Solid Edition is of greater interest in mining or well-boring operations, while the Drift Edition is the one more likely to be of use to the agriculturist. These maps are published on scales of ¼ in. and 1 in. to the mile, in colours, for a considerable proportion of the country. There also exist similar maps on a scale of 6 in. to the mile in the records of the Geological Survey, where they may be examined. On some sheets a certain amount of information about the soil has been inserted. The work of the survey goes on continuously, and probably the Drift Maps will become more and more useful agriculturally. For estates and

large farms a copy of the drift map of the locality is a useful acquisition. Of maps whose purpose is the portrayal of soil conditions, there are unfortunately very few available. There exists one sheet, on the 1-in. scale, published by the Geological Survey (No. 22 Sheet, of the area around Kilmarnock) which maps the soil texture. This, with the corresponding Drift and Solid Editions, serves to show to a certain extent the connection between geological and soil conditions and the limitations of geological maps, especially Solid, when applied to soil work. Work on soil surveying has, however, been carried on in this country for a long period of years. It has largely been in the hands of educational institutions and has resulted in a number of useful reports on the soils and agriculture of limited areas, generally on a county basis. Thus there is in the possession of almost every agricultural college, department or advisory centre, a useful mass of information about the soils of the locality whose needs it endeavours to meet. In some few cases, more detailed surveys, on a field to field basis, are in progress. This type of work is being steadily developed and will ultimately result in soil maps of great utility to the agricultural industry. That the task of mapping soils is not so easy as at first sight it might appear, can be realized when the numerous respects in which soils vary are borne in mind. To map on a texture basis is fairly straightforward, but there are other characteristics of great economic importance which must be taken into consideration, such as conditions of drainage, reaction or lime status, amount of humus, amount of reserve mineral plant nutrients, depth of soil, and nature of subsoil, so that it will readily be admitted that to give adequate expression to all these points by means of a map necessitates some system of classification for soils.

Connection between Geology and Soils.—To return to the geological basis of soil formation, there are several easily observed phenomena which demonstrate this. Almost any quarry face will show on inspection a gradual transition between the original solid rock and the surface soil, such as depicted in Fig. 1. As the eye travels upwards it will be noticed that cracks and fissures appear and grow more definite until separate masses of rock appear. These become smaller, the joints more numerous and more open. Soil appears between the rock fragments, the general appearance is more brashy, and, at a still higher level, the predominant constituent of the mass is obviously soil, and finally the top few inches becomes generally darker in colour and is found to contain the root systems of the herbage growing on the surface. Throughout the transition the parent rock and its more obvious characteristics can be readily traced. A section of the earth's surface, such as above described, is termed a "Soil Profile," and it is by studying the varying profiles of the soil and the factors which govern their development, that many of our present-day soil scientists are endeavouring to systematize our knowledge of the soils of definite regions and of the world as a whole.

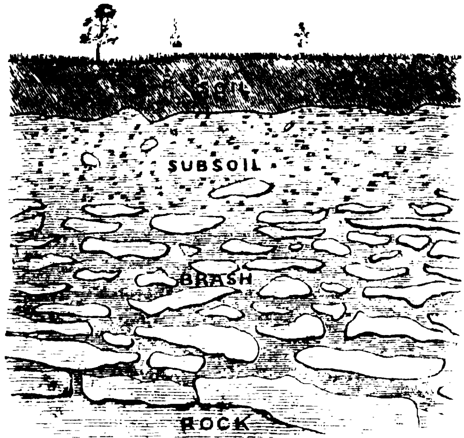


FIG. 1.—Diagram illustrating the formation of a sedentary soil on the Oolitic limestone of the Cotswold Hills, Gloucestershire.

Composition of Rocks and Minerals.—It is obvious that the parent material of most soils must be the rocks, so that it is logical to study these first. Examination of a collection of rocks from different localities enables them to be sorted roughly into three main groups—Igneous, Sedimentary and Metamorphic. Their main features can best be seen by comparing the surfaces of a freshly broken piece of granite and of a piece of a conglomerate such as Hertfordshire pudding stone. (An example of a conglomerate produced by artificial means is provided by a piece of concrete.) The former is seen to consist of large white or pink crystals, together with much smaller dark or black crystals firmly set in an irregular mass of whitish crystalline material. As more and more examples are studied it is seen that these three distinct constituents, together with others, occur over a wide range of rocks. Each has its own particular colour, crystalline form and chemical composition. In fact, they are definite chemical compounds, and the three occurring in granite are the minerals felspar, mica and quartz. Crystalline form is essentially characteristic of a definite chemical composition and occurs when a chemical compound separates out from a solution or from a molten mass. The rate at which cooling takes place decides the size of the crystals; slow cooling leading to large crystals and *vice versa*. Granite, then, is a solid mass of three distinct minerals formed by the cooling of a molten mass of material, and affording a good example of an igneous rock. Pudding stone, or concrete, on the other hand, reveals a different structure. Both are made up of pebbles of various sizes cemented together by material of much finer texture. In the case of a pudding stone, closer examination shows that the nature of the component particles, apart from size, shows certain constant

features, of which the most notable is that all the particles are rounded, whether they be large or small. In the case of the larger, it can be seen that they are rock fragments in themselves, re-cemented together. The rounding of the surfaces indicates long continued rubbing together, such as would be undergone during transportation by running water. Thus it can be seen that a conglomerate is made up from fragments of other rocks which have been transported from their original locality by water or other agency and subsequently recemented together by chemical action. Such a rock is an example of a sedimentary rock. The metamorphic rocks, as their name implies, appear to have been derived from the other types by the subsequent action of great pressure or heat, resulting in more or less marked changes in their chemical and physical characteristics.

It is worth while to consider these three groups in a little more detail. The Igneous Rocks, as has been indicated, appear to have been formed by the cooling of original molten material and are characterized by complete crystallization. They are classified on their chemical composition and physical texture. The former will be seen to be of great importance when it is realized that the make-up of rocks in general includes silica and the oxides of aluminium, iron, calcium, magnesium, potassium, sodium, titanium, sulphur, carbon, and phosphorus, listed roughly in the order of their abundance in the earth's crust. They occur in amounts which fall off rapidly in this order from silica at about 60 per cent., aluminium oxide 15 per cent., calcium oxide 5 per cent., potassium oxide 3 per cent., down to phosphorus oxide 2·5 per cent. Of these constituents, the most prominent, silica, and the least abundant the oxides of carbon, sulphur and phosphorus, are acid constituents, while the oxides of most of the metals are basic. Thus, on the basis of the amount of silica present, an igneous rock can be described as acidic, intermediate, basic or ultrabasic. The intermediate and basic sub-divisions can be further split into those whose bases are chiefly the oxides of potassium and sodium, when they are described as "alkaline," and those whose bases are chiefly the oxides of calcium, and magnesium, when they are described as "subalkaline." It will now be realized how the chemical composition of the rocks can influence that of the soils derived from them, especially as regards the important constituents of potash and lime. Coupled with this chemical basis of classification is the physical, based on characteristics determined by the conditions under which the rock solidified. Thus, rocks found at a great depth would cool and solidify very slowly, giving large crystals; such are described as "Plutonic." Those formed as a result of the eruption of molten material and subsequent rapid cooling on the earth's surface have a very fine structure, which is either spongy and porous, or glassy. Such are the "Volcanic Rocks," of which lava and pumice are examples. To consider one or two examples in the light of the above classification: granite is a Plutonic acid rock, having a coarsely crystalline

structure of felspar, mica and quartz ; pumice is a Volcanic acid rock of similar composition but of very light microcrystalline structure ; basalt is a Volcanic basic rock, whose chief constituents are a felspar and compounds of iron, magnesium and silicon ; serpentine is a Plutonic ultrabasic rock of obviously crystalline form, containing no felspar or quartz but large amounts of ferro-magnesian silicates and oxides of iron.

The Sedimentary Rocks are almost all made up of fragments of older rocks and have been formed by various agencies. The largest group are those transported, sorted and laid down by physical agencies, such as wind, water or ice. Such are the conglomerates, already described, and sandstones, containing grains of quartz, felspar, etc., from igneous rocks, coloured by iron and cemented together in a new rock form. There are also the clays and shales, deposited by rivers or wind in former seas, estuaries or lakes, and the sands and gravels. A less abundant but still important group is of organic origin and the most important members of this are the chalks and certain limestones which are composed of accumulations of the shells of marine organisms of various sizes, still recognisable as to their structure.

The Metamorphic Rocks are of less interest from the point of view of soil work, but slate may be quoted as an example of a definite rock formed from shale by physical agencies acting on it subsequent to its original formation.

The sequence of events in the earth's history was probably as follows :—Presuming it to have been formerly a molten mass at a high temperature, the oldest rocks would be mostly of the igneous variety. Once a shell of such material had begun to form, local variations of temperature would provide the beginnings of a climate. Sea and land would be established, but from time to time gigantic earth movements would bring about an entirely new geography of the earth's surface with a new distribution of climate. During every such era physical agencies would be at work on the exposed rock face, weathering it, transporting it and laying it down elsewhere to form new rock masses. It is on some such line of thought that the present constitution of the earth's crust can best be understood.

If a bore hole is sunk in the neighbourhood of London it passes successively through the rocks in the order of their age or formation, beginning with the youngest, *i.e.*, the most recently formed. Moreover, if the surface of the land is examined along a line starting from this bore hole and proceeding in a north-westerly direction, the same rocks are encountered outcropping successively in the same order so that it becomes apparent that the strata of the rocks are inclined from the north-west to the south-east. Except then, where the outcrops are masked by a layer of the most recent geological formations, such as the various drifts (Alluvium, Gravels, Boulder Clay), the soil is the result of the weathering of the geological outcrops.

Effects of Weathering.—The process of weathering is the result partly of the operation of physical forces and partly of chemical action on the original rocks. Variations in temperature produce expansion and contraction of the rock materials, and as these do not all behave alike in this respect, stresses are set up in the material as a whole and shattering ensues. Water enters the joints and cracks in the rock mass, and if freezing occurs, the resultant expansion is comparatively large and an enormous disruptive force is developed, with the result that the rock is more widely split. Running water or glaciers carry pebbles and boulders with them, grinding them together and against the surface over which they move, thus carrying the process of disintegration still further. Finally, small particles carried along the surface under dry conditions by the wind, also cause and themselves undergo a further powdering action. All these actions have their effect simply on the size and shape of the fragments produced, the disruptive forces resulting in rough jagged particles, and the transporting agencies rounding and smoothing their surfaces.

Of the chemical actions at work, that of water is the most potent and widespread. It dissolves, very slowly it is true, the material of which the rock particles are composed and sets up chemical action on its constituents. Its solvent action is considerably enhanced by the fact that rain in its passage through the air dissolves a certain amount of carbon dioxide and becomes a weak acid. This is increased by further contact with carbon dioxide on percolation through the surface soil. The general trend of the actions which then take place is to split up the complex compounds (chiefly silicates) of the minerals in the rocks, to remove in solution certain of the simpler substances which result, and to leave a residue of the others. These decompositions and their results are very complicated because of the large number of varying factors involved, but here again the original composition of the rock and the prevailing climatic conditions both have an important influence on the issue. To consider a specific case, such as the weathering of a felspar, a silicate of potassium and aluminium, the net result is the removal of potassium as a soluble salt (potassium carbonate) and the accumulation of hydrated aluminium silicate, which is a clay.

Soil Profiles.—Weathering proceeds in soil also, as well as in the original rock from which the soil was produced, with the formation in many cases of a definite profile, in which very frequently the alteration of the soil particles and the movement of the products of weathering have gone on to such an extent that the effects become visible to the eye in the different layers of soil seen in a vertical section. It is by a study of these soil profiles, when exposed in vertical sections (freshly cut) from surface down to parent rock, that the new ideas of soil classification are being advanced. The differing horizontal layers found in a profile are termed "horizons." They can be distinguished by colour, texture and chemical analysis.

The following brief descriptions of two soils in profile will serve to illustrate these points :—

HEAVY CLAY SOIL ON GAULT (CAMBRIDGE).

Surface to 2 ft. 6 in.—
Yellowish-grey heavy clay.

2 ft. 6 in. to 3 ft. 6 in.—
Blue-grey clay, with orange-brown mottling.

3 ft. 6 in. to 5 ft. 6 in.—
As above, but with pockets of white crystalline material, mostly calcium carbonate.

5 ft. 6 in. to 7 ft.—
Blue-grey clay.

COARSE SANDY SOIL ON BARTON BEDS (NEW FOREST).

Surface to 5 in.—
Very black sand.

5 in. to 1 ft. 6 in.—
Greyish white sand.

1 ft. 6 in. to 3 ft.—
Compacted black sand.

3 ft. to 4 ft.—
Dark brown sand.

When the various horizons are analysed and systematically studied, considerable light is thrown on the soil formation processes and also on the behaviour of the soils under various forms of cultivation and manurial treatment.

Biological Factors in Soil Formation.—While the processes of weathering were producing the mass of mineral particles of which most soils are composed, various forms of life on and in the soil were also being evolved, and these in turn have exerted their specific effects. The most obvious of these are plants, with their stems and leaves in the air and their root systems in the soil. Plants normally develop from their seeds which, given the suitable surroundings of air, moisture and temperature found in most soils, germinate and produce both a root and a shoot. If the supply of food material in the seed suffices to enable the shoot to reach the outside air, this produces small green leaves which are able by means of the energy derived from the sun to assimilate carbon from the traces of carbon dioxide present in the air. At the same time the rootlet absorbs nutrient material from the soil moisture, which provides the medium by which small quantities of the mineral matter of the soil become assimilable. The substances thus absorbed, in a simple chemical form, are elaborated by the plant into more complex organic compounds such as carbohydrates, oils and proteins, with which it builds up its structure and makes its growth. When the plant dies it decays and forms, in the soil, the organic matter known as "humus."

In addition to the plants visible upon its surface, the soil teems with living organisms of many different kinds, from earthworms and insects down to microscopic forms such as bacteria, all playing their part in the development of the soil complex. In the past half century those extremely minute organisms known as bacteria have been the subject of much research work. It is now known that many of them are dependent for their energy on that stored up by plants during their period of growth and returned to the soil on their death. The significance of bacteria in many of the changes which organic matter undergoes when added to the soil has been

worked out, and a much more detailed knowledge of soil phenomena is now available. It is to be expected that what might be termed the living or active part of the soil is the surface layer, and examination of the profile generally shows this to be the case. The amounts of organic matter, insect life, bacteria and plant roots steadily and fairly rapidly decrease with increasing depth, so that in the soil, from the point of view of its employment for crop production, the topsoil and subsoil have very different properties and capabilities —a fact of great importance in connection with such questions as the depth of ploughing, the value of subsoiling, the most suitable system of cropping, and so on.

So far the soil has been considered from the point of view of its development and of the natural phenomena which influence it. Enough has been said to show that the important factors, from a utilitarian point of view, are probably the composition and properties of the mineral and organic portions, the conditions of moisture, temperature and aeration within it, *i.e.*, the soil climate, and the nature and function of the living organisms within or on it. Once the measure of these has been taken, it ought to be possible by artificial means, whether of cultivation, manuring or cropping, to influence its productivity to a considerable extent.

Colour.—On walking over arable land, the first characteristics of the soil to strike the senses are its colour and texture. The number of distinct colours encountered even in this country is very large, so large, indeed, that it is impossible to describe them at all accurately. A journey through the countryside leaves one with definite impressions of black, white, red, brown, yellow and grey soils in different localities, but if samples of all the brown soils be taken and set out side by side on a table, the observer will be astonished to find how many very distinct colours come under the one description " brown." The same holds good for the others, and moreover, striking differences are found in the colour of any one sample when it is dry and when it is moist. Again, the colour is greatly influenced by the direction and amount of sunlight, some soils which, in ordinary daylight, are a nondescript brown, assuming a definite red appearance in sunlight. The colour is partly due to the mineral constituents and partly to the amount and nature of the organic matter. Black soils owe their appearance largely to the dominating influence of the organic matter in them ; cases in point are the soils of fens, river alluvium, and old gardens. This effect can also be demonstrated if the average soil is exposed in a vertical section, the larger amount of organic matter in the topsoil giving it a darker colour than the subsoil. White and grey soils may owe their colour to one of several causes. The commonest of these is chalk, and white or light greys are abundant in those districts where the soil merges insensibly into the chalk rock. These light colours are also found on some very clayey soils and also some of the coarsest sands. In the latter case, the colour is, as a rule, due to the leaching out by weathering of the oxides of iron, the other

important colour-giving constituent of soils. The richer hues of yellow, brown and red are due to these same iron compounds. When an ordinary dark-coloured English soil is ignited for some time at a bright red heat and then allowed to cool, the residue is found to be brick-red in colour, owing to the destruction of the organic matter which gives it its dark shade. When this has been eliminated the effect of the iron compounds in the soil becomes more apparent in the resultant red colour. Now, if another portion of the same soil is digested for a while with hydrochloric acid and the resulting solution washed away, the residue is found to be black, and if this is carefully dried and then ignited strongly like the first sample the final residue, composed mainly of silica, is almost white. In this experiment, the treatment with acid removes most of the bases, including iron, first, so that the organic matter is the colouring constituent which is dominant, and on this being removed by ignition, the residue is colourless or white.

Texture.—Walking on the land is one of the most telling ways of getting an idea of the texture of the soil. During wet weather, one's experience ranges from slippery, sticky soils at the one extreme, on which walking is difficult, which tenaciously accumulate on one's boots, and in which the moisture is obviously excessive, to soils at the other extreme which do not adhere to one's boots to any extent, on which walking is comparatively easy, and which show no signs of excessive moisture. In droughty times, on the other hand, the former conditions are replaced by those of hard clods or of a rock-like surface, broken by numerous cracks of various dimensions, while the latter give place to those similar to a loose, dry layer of sand in which one's boots sink owing to the lack of cohesion amongst the particles. These phenomena of soil texture are primarily due to the make-up of the soil in respect of particle size. If a handful of ordinary soil be taken up and examined closely by eye or by the aid of a pocket lens, it is not difficult to see that the mineral particles are of all shapes and sizes from obvious pebbles downwards. If a little of the soil is moistened and rubbed between the fingers the gritty nature of the larger particles is revealed even when to the eye the proportion of them is extremely small, and at the same time it may be realized that the greasy feel and stickiness of a soil is an attribute of its finer particles. In ordinary parlance, the terms gravel, sand, silt and clay express some of these differences of size and stickiness. To give precision to such terms and to facilitate analytical comparisons between different soils, there has been evolved a convention with respect to particle size. On this convention the term "soil" implies all those individual particles which have a diameter less than 2 millimetres, and those which are larger are considered as stones. In the natural condition, as has been seen, the soil particles are not all separate from each other, but are aggregated in crumbs of all sizes. For the purpose of analysis on a particle size basis, any soil sample must undergo a preliminary treatment to destroy the crumb. When this is accomplished the

coarser fragments can be separated by sieves whose meshes are made of an appropriate size. Unfortunately, a great proportion of the particles of the "soil" in many cases are smaller than the meshes of the finest sieves practicable for this work, so recourse must be had to another method of separation, based on the fact that particles of the same material, but of varying sizes, sink through a liquid medium, such as water, at varying rates dependent on their diameters. In this manner, by sieving and by sedimentation, any soil sample can be divided into fractions whose diameters lie between the following limits :—

Gravel and coarse sand ...	2–·2 mm.
Fine sand	·2–·02 ,,
Silt	·02–·002 ,,
Clay	Less than ·002 mm.

The process is known as "mechanical analysis."

Properties of Soil Fractions.—From these figures it will be seen that the average diameters are in the ratio of 1100 : 110 : 11 : 1, so that in the soil proper the size of particles, comparatively speaking, varies enormously between the extremes of sand and clay. When these soil fractions are examined in bulk, some of their properties are obvious. Coarse sand shows practically no cohesion and allows free drainage of water through it ; fine sand does show cohesion, especially on drying, but is easily crumbled once more and allows free movement of water through it ; the other two fractions, especially clay, cohere very tenaciously and offer considerable resistance to the movement of water through them. To the extent that these properties cannot be altered by artificial treatment, it is clear that a predominance of any fraction in a particular soil will impress on it its own particular characteristics. The connection between the size of the particles and the properties of the fractions centres largely on the total surface area of the particles in any given volume and the calibre of the spaces between them. The effects can be visualized if each fraction is imagined to be composed of one size of particle whose shape is spherical. Large particles inevitably mean large interspaces, but the total amount of interspace in any given volume will be decided by the closeness of packing of the particles rather than by their individual size. But when the surface area of the solid particles in a given volume is determined, the size of particles has an enormous effect. Imagine a cubical box containing a sphere which fills it, *i.e.*, which touches all six sides, and another of the same size divided into eight equal cubical compartments each with a sphere filling it in the same way. Each sphere must occupy the same proportion of the volume of its containing cubical box, so that the amount of space left unfilled in each of the two cases is the same. But if the total surface areas of the spheres be worked out in each case, it is found that the sum of the areas of the surfaces of the eight small spheres is twice as great as that of the single sphere occupying the same space. Stated briefly, the total surface area of the particles

in a given volume is inversely proportional to their diameter. One worker puts the internal surface area of a cubic foot of sand at 6,000 sq. ft. and of 1 cubic ft. of clay at 100,000 sq. ft. If these surfaces are visualized as covered by a uniform film of moisture, the connection between the water-holding powers of the various sized fractions begins to reveal itself. There is a further connection between this factor and the property known as tenacity, which is the result of forces working in the water film.

Moisture in Soils.—The following table gives some results of a few simple experiments on the connection between various sizes of particles, the air space amongst them, and their power to retain water.

100 cc. of soil particles between—

5 and 3 mm.	in diameter	contain	48 cc.	air space	and retain	7 cc.	water.
1	,,	,,	45	,,	,,	9	,,
1	,,	,,	50	,,	,,	15	,,
·5	,,	,,	57	,,	,,	31	,,
·2	,,	,,	55	,,	,,	34	,,

It will be noticed that as the size of particle diminishes, the total air space does not alter very considerably, but the amount of water retained under free drainage conditions increases rapidly.

A comparison of a few prominent soil types in a similar manner gave the following results :—

Type.	Apparent Density.	Air Space per 100 vols.	Water Held per 100 vols.	Drainage.
Sandy	1·45	40	12	Rapid.
Loam	1·21	50	27	Fairly quick
Heavy clay	1·01	60	35	Very slow
Peaty	·34	80	42	,,

The same points are again illustrated, but in addition other facts of interest are revealed. Assessed on actual weight per volume, the heaviness of the soils is in the order of sand, loam and clay, which is the reverse of the order of heaviness experienced by the farmer working them. His "heaviness," of course, does not refer to actual weight but to the ease with which they can be cultivated, and is more a matter of their tenacity. It can be seen, also, how the loams fall into an intermediate position between the sands and clays in respect of all these properties. So far as its mineral particles are concerned, a loam is made up of a fairly even mixture of all sizes of particles, neither sand nor clay predominating. The figures for peaty soil show also the effect of the characteristics of organic matter in a soil, in lightening it (literally), in aerating it and in improving its water-holding capacity. The figures also illustrate the importance of texture in drainage and also in the ability of a soil to raise water from below and to retain it. Of late years it has come to be realized how complicated are the water relationships of soil. By working on "ideal soils," *i.e.*, soils composed solely of spherical mineral particles of equal diameter, physicists have been able to

elucidate some of the complicated forces involved. The manner in which water can rise from a water-table into such a dry soil can be seen to be dependent on the size of particles, and so on the frequency of points of contact between the particles, the distances between these points, the shape of the interspaces and their calibre. It would appear that water starting from any point of contact between particles begins to spread over their surfaces and to fill up the angles between them until it touches a similar spread from some other point of contact. The sides of the spaces being thus wetted. the water tends to fill up the core and obliterate the air space. This process goes on until the forces involved are insufficient to fill the whole of the air space, and at about this level the water-table is formed. But the water is still able to spread on the particle surfaces and to continue to rise, although the interspaces continue to hold air to an increasing extent. At this stage this conception of moisture relationships can be applied to field conditions. If rain occurs the added water tends to flow down into the soil *via* the film of water surrounding the particles, until it reaches the zone of saturation or water-table, the level of which is thereby raised. The rate at which it can do this is determined by the texture of the soil. If the rain falls too heavily the system of interstices must become comparatively air-locked and standing or running water will appear on the surface. On heavy land this condition tends to become almost permanent in the wet season and yet, on digging, the soil at lower depths may show no signs of water-logging. In dry conditions, the movement of water in soils has a general upward trend ; moisture is evaporated from the surface and is replaced by more moving up from below, with the result that the water-table is lowered. Where the rate of evaporation at the surface exceeds the rate of rise from below, the soil begins to dry out to an increasing depth, but at a decreasing rate. Advantage is taken of these phenomena to regulate artificially the moisture conditions just below the surface soil. In the absence of rain, and at spring-seeding time, a steady supply of moisture from below to the germinating seeds can be ensured by rolling and so consolidating the seed-bed. This operation will also, however, at the same time lead to an increased loss by evaporation from the surface, a drawback which can be removed by a subsequent light harrowing. This loosens the top inch or two of the soil, which dries out more rapidly, and soon becomes a protective mulch to the soil below, in which the seeds lie. It is for these reasons that the hoe is regarded as more useful than the watering can in establishing optimum water conditions in gardening operations.

Types of Soil.—All soils composed mainly of mineral particles can be classified as sandy, loamy or clay soils. These broad groups can be further sub-divided, as, for instance, into light, medium or heavy loams, or they may even be given a description which attempts to put into words the mechanical analysis. This frequently results in extraordinary contradictions in terms, *e.g.*,

"a fine, sandy clay." This expression, however, simply means a soil made up chiefly of clay particles and particles of fine sand. The following table gives some examples of soils classified by touch, with their mechanical composition alongside :—

	Coarse Sand.	Fine Sand.	Silt.	Clay.
Very coarse sandy soil ...	72	19	3	2
Sand soil	45	32	10	8
Light loam...	41	29	14	9
Medium loam	24	21	25	20
Heavy loam	25	9	24	29
Clay soil	18	9	21	36
Heavy clay	6	4	30	49
Heavy silt	1	17	59	13

In this table the grades of particles are only four in number. Differences in texture may arise even by the predominance of particles of sizes within these limits, as, for instance, in the case of silt, of which the finer grade, approximating more and more to the size of clay particles, assumes more and more the stickiness of the latter, without the compensating advantage of being amenable to the improving effects of judicious cultivations or liming.

Texture and Cropping.—There is an intimate connection between the mechanical analysis of most soils and the uses to which they are put in crop growing. In an area such as the south-eastern half of England, which enjoys fairly uniform climatic conditions, especially in the matter of rainfall, the distribution of particular crops and the extent to which they are grown on a particular type of soil enables one to point to a definite texture as being most suited to each crop. Soil surveying on these lines indicates that the most frequent composition of soils devoted pre-eminently to wheat-growing has a make-up of the following type :—

Coarse sand	5 per cent.
Fine sand	24 ,,
Silt	36 ,,
Clay	20 ,,

It is, of course, possible to grow wheat on soils with mechanical analysis figures outside the ranges indicated, and modern work has resulted in the production of varieties better suited to one type of soil than to others, a recognition in itself that factors such as texture influence crop results. Similar observations are summarized in the following table for other crops :—

	Barley.	Potatoes.	Beans.	Market Garden Crops.	Nursery Stocks.
Coarse sand ...	1	21	15	54	17
Fine sand ...	25	45	10	15	66
Silt	43	16	29	14	8
Clay	12	8	30	6	4
General texture	Light loam.	Sandy.	Clay.	Sandy.	Fine sandy

Thus far we have considered texture solely from the point of view of the size of the particles in the soil. There are, however,

two constituents, present in most soils, which are sometimes found in such quantities as to mask entirely the physical properties of the various-sized mineral particles. They are chalk and organic matter, the latter familiarly described as humus. The amount of chalk may vary from 0 up to 70 or 80 per cent. Its effects are, briefly, so to ameliorate the stickiness due to the clay fraction that soils with a high amount of this constituent work more easily than they otherwise would, while lighter soils tend to become very spongy, to puff up and to lift in winter, while continuing under certain conditions of moisture to be sticky and tricky to work. This is the case with chalky soils containing more than 30 per cent. of chalk. Organic matter also, as its amount increases, can impress definite characteristics on a soil, regardless of its mechanical analysis. Peats, fen soils and riverside alluvial flats are cases in point.

Some of these differences and their effects are illustrated by the following analysis of three types of soil, obtained on one farm of about 500 acres.

	London Clay.		Valley Gravel.		Alluvium.	
Formation.	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.
Coarse sand	27	15	42	41	6	9
Fine sand ...	22	17	26	25	8	13
Silt	27	29	19	17	34	25
Clay	13	26	6	11	22	31
Organic matter ...	6·0	5·3	3·9	2·8	18·3	10·2

In the case of each type it will be noticed that there is less organic matter and more clay in the sub-soil than in the soil, and in the first two examples, both typical mineral soils, the subsoil contains a noticeably smaller amount of the coarser fractions, facts which are connected intimately with the common observation that subsoils as a rule are lighter or brighter in colour and more sticky, raw and unkindly, than the soils which lie above them.

Clay.—The clay fraction seems to exert the largest effect on the properties of the soil as a whole. The clay particles are extremely minute, many of them so minute as to be beyond the range of visibility even of a microscope. If a heavy soil be shaken up in soft water for a time and allowed to stand, the water remains turbid for an indefinite period, owing to the fine clay particles remaining in suspension. The individual particles cannot be distinguished by the eye but if, after a day or two, some of the turbid liquid is poured into another clean glass vessel it will be seen that they do continue to settle out slowly and form a thin but very compact layer on the bottom. If a very thick suspension is made in a similar fashion, and to it is added a small quantity of an acid, with subsequent shaking it will be observed that particles soon become visible in the suspension, looking like gelatinous flakes which settle out comparatively quickly to give a voluminous sediment at the bottom. In the original condition, with the particles free and separate, the clay is said to be "deflocculated," while in the latter, under the influence of the added acid, the particles have coalesced or run together in

groups, in what is known as the "flocculated" state. The acid is termed a flocculating agent. The conditions of the clay in the two cases may be compared respectively to those of the individual seeds picked from a blackberry and of the berry as a whole. Although the analogy is not strictly true, it serves to illustrate the behaviour of clay. Imagine, for instance, two jars, one filled with the seeds picked from a blackberry and the other filled with whole berries; the former would resemble deflocculated clay in the field condition, a dense sticky or firmly compacted mass, while the latter would resemble clay in the flocculated condition, loose, crumbly and easily broken down. It is easy to see that a heavy wheel or a horse's hoof, pressed on to whole berries (or flocculated clay when moist), would produce a sticky mass of crushed berries (or "puddled" clay). These phenomena in clay are intimately connected with its "colloidal" nature, a term applied to many substances which can assume the physical condition associated with jelly, or white of egg. There is much evidence to indicate that the surface of the soil particles is covered with a layer of material in this condition. If this is the case colloidal properties will become more evident as the internal surface area per unit volume of soil increases, *i.e.*, as the particles become smaller. It is the interaction between this colloidal surface of the particles and moisture which causes the swelling and shrinkage associated with the wetting and drying of clay. When a measured volume of puddled clay is allowed to dry out it is found that shrinkage takes place and that the rate of shrinkage is constant down to a certain moisture content, after which it falls off. Whatever the cause of this lag may be, it is an established fact that on gradual re-wetting the volume of clay expands correspondingly but more rapidly at first and more slowly later. A repetition of the drying does not produce the same shrinkage as the first drying and so on. It would appear that these alternate dryings and wettings cause the particles, by some change in the condition of their colloidal covering, to loosen themselves from one another and in practice to make the whole mass more friable and crumbly. These phenomena are of great importance in tillages, and especially in connection with the production of a seed-bed. It is not enough for clay clods simply to be dried down to a certain optimum moisture content to make them friable. This state only appears after the drying has proceeded further and has been followed by a remoistening. If this has happened more than once, so much the better. The value of these changes is the more important in the absence of frost, with its largely enhanced shattering effect caused by the increase in volume which takes place when water freezes.

Soil Temperature. "Earliness" or "lateness" of soils is a factor of great importance in the uses to which they are put, and depends very much, though not solely, on their texture. Their original source of heat is the sun, so that for any field the first influence on the temperature of the soil will be the amount and

direction of the slope. The rays of the sun falling on the earth are parallel and of even intensity per unit of area, so that the amount of heat falling on each unit of area of the soil will be at the optimum in the case of fields sloping in a southerly direction. The next factor concerned is the colour of the soil for, roughly speaking, the darker the soil is the more heat it will absorb and retain from the sun's rays. Perhaps the most potent factor, however, is the moisture in the soil. The heat is used up in raising the temperature of the mineral matter of the soil and of the moisture in it and in evaporating water from its surface layer. Now, the amounts of heat necessary to raise the temperature of equal weights of mineral matter and water by 1° and to convert the latter into water vapour are respectively in the proportions of 1 : 10 : 540. Thus it will be seen that under similar conditions of aspect and colour, the heavier soils, with their greater moisture-holding power, will always require much longer to warm up under the sun's influence, so that they will always be colder and later (in spring a heavy soil will frequently contain 30 per cent. of moisture by weight).

Chemical Composition of Soil.

Mineral Matter.—So far the soil has been considered solely from the point of view of its physical constitution. It is necessary now to deal with its chemical composition. This is best done by describing the various fractions in the mechanical analysis. The sand, silt and clay are all fragments derived from the original rocks by weathering. The rocks themselves are made up of minerals which have a definite chemical composition. Briefly, the main compounds in rocks are silica, and the more complex silicates, in which the silica is associated with the bases aluminium, iron, magnesium, calcium, sodium and potassium, so that the same sort of compounds will probably be found in the mineral particles of a soil. If the soil has been produced directly from the older igneous rocks, it will be much less weathered than if it has been produced on a geological formation of comparatively recent date. If soils from North Wales or the North of Scotland be compared with soils from East Anglia, it is found that the coarser particles of sand and gravel contain an appreciable amount of comparatively unweathered minerals and silicates, while the similar fractions of the latter contain very little except the quartz residue or silica. Further, in comparing the different fractions of one of the latter soils, it is found that the less weathered materials are to be found more in the finer particles. As a rule sand is largely simple silica, while the clay fraction is made up of more complex compounds in which the silica is associated with various bases, the most important being calcium and potassium.

Humus.—The organic matter, usually termed humus, has been already attributed to the gradual accumulation of the remains of organisms, chiefly plants, which have flourished on or in the soil. Some of it is recognizable as such by the persisting structures of

stems, leaves and roots. A certain amount, however, has been comminuted by some means or other to a state in which no recognizable structure remains and in which it exists as a uniform spongy dark brown or black material. The composition of the organic matter is very complex. It is useful to regard it as being made up of a large number of organic compounds derived from plant material. A feeding stuff consisting of dried plant substance is described on analysis as containing water, proteins, fats, carbohydrates (sugars, starches, etc.), fibre and ash, and this terminology is a useful basis on which to visualize the composition of humus. Such is the collection of materials which falls back on to the soil when a plant dies, and from it humus is formed, by a series of chemical changes brought about by the activities of various types of bacteria, working chiefly on the proteins and carbohydrates. Now, of the constituents named above, the carbohydrates are made up of carbon, hydrogen and oxygen, while the proteins contain, in addition, small amounts of nitrogen, sulphur, phosphorus and calcium (the ash). The nitrogen is the most valuable of these and is the one of which the humus constitutes a reserve supply in the soil. To sum up, the humus is a complex of organic compounds which gives to the soil a darker colour, aerates and opens it, makes it drain more freely and at the same time enables it to retain more moisture when drained, helps tilth formation and provides a reserve of nitrogen. Many of these powers it owes to its colloidal nature, so that, dispersed amidst the soil particles, it will tend to give to them a colloidal covering. In ordinary soils the nitrogen constitutes roughly 3 per cent. of the organic matter, so that, as the following figures illustrate, great variations in the amount of this plant nutrient are found; in light, sandy soils it is as low as ·05 per cent., in average arable land ·05 to ·2 per cent., in grassland ·15 to ·4 per cent., in peaty soils ·7 to 2 per cent.

Three other constituents of ordinary soils are of importance. Chalk, or calcium carbonate, is a comparatively simple chemical compound whose amount in soil varies considerably. It has important bearings on its fertility and tilth (p. 29). Phosphates are important also as one of the chief plant nutrients, being found partly in an original mineral form, as calcium phosphate, and partly in the organic portion or humus. Lastly, there is the water which is present, distributed over the surfaces of the particles of soil throughout its structure. The solvent power of water has been mentioned, and it is only necessary to add that in contact with materials of such varying composition as have been described, it produces a "soil solution" in which very small quantities of all these substances are dissolved to an extent determined by their solubility. This soil solution is the main channel by which the plant nutrients in the soil find their way beneficially to the roots of growing plants or wastefully into the drainage water. The concentration of the soil solution rarely exceeds ·1 per cent., and the chief substances found in it are nitrates, bicarbonates, organic

matter, calcium, sodium, magnesium, silica, chlorine, sulphates, potassium, ammonium, and phosphate.

Analysis.—Shorn of its chemical formulae, the analysis of a soil is illustrated by the following example :—

	Per cent.
Moisture	3·78
Loss on ignition (or organic matter)	5·16
Nitrogen	·152
Calcium carbonate (or chalk)	·03
*Oxides of iron and aluminium	6·56
*Total calcium oxide	·510
*Total magnesium oxide	·371
*Total phosphoric oxide (or phosphoric acid) ...	·123
Available ,, ,, ,, ,, ...	·013
*Total potassium oxide (or potash)	·248
Available ,, ,, ,, ...	·016
Matter insoluble in acid (or silica)	81·0

The general custom is to express the constituents in terms of their oxides, but this does not mean that the oxides are actually present as such. For instance, all the calcium present in this sample is equivalent to ·51 per cent. of calcium oxide and is expressed as such. In actual fact, some of it is present as the ·03 per cent. of calcium carbonate, some as calcium sulphate, but most as unweathered or partially weathered mineral silicates in the soil particles ; there is no free calcium oxide, or quicklime, present. The constituents marked with an asterisk are those which are dissolved out of the soil by extraction with hot acid for a considerable time, and the last item (silica) is the undissolved residue in this extraction, after ignition to remove all the organic matter. The total does not account for a full 100 per cent., but there are other constituents present in small quantities which do not appear in the analysis. The other items are estimated separately, nitrogen, of course, being part of the organic matter but determined independently because of its importance. Again, the "available" constituents form part of the totals of the same name, but being more easily soluble they are estimated by other more appropriate methods. There are several other analytical data frequently obtained in advisory work on soils but most of them deal with the condition of the soil or of some of its constituents, and so are more of a qualitative nature ; such are reaction, acidity, lime requirement and amounts of exchangeable bases.

The value of chemical analysis lies in the light which it throws on the composition of different soils, the explanation of some of their properties, and the elucidation of some of their peculiarities or shortcomings when used for crop production. The three types of soil quoted with reference to the variations in texture on one farm (*v.* p. 15) will serve to show some points of significance in their chemical composition.

	London Clay.		Valley Gravel.		Alluvium.	
	Soil.	Subsoil.	Soil.	Subsoil.	Soil.	Subsoil.
Organic matter ...	5·98	5·26	4·78	3·50	18·30	10·18
Nitrogen	·174	·084	·161	·098	·695	·286
Clay	12·6	25·7	3·7	5·0	21·7	31·0
Oxides of iron and aluminium	8·09		3·39		16·30	
Calcium oxide	·500		·550		1·04	
Magnesium oxide ...	·261		·330		·867	
Potash	·332	·592	·147	·172	·492	·635
Phosphoric acid ...	·092	·061	·092	·073	·243	·169
Calcium carbonate ...	·07		·38		0	
Calcium oxide ...	·500		·550		1·04	

A perusal of these figures illustrates several points. (1) The amount of nitrogen varies with that of the organic matter, but the subsoil organic matter contains relatively less of this constituent. (2) The heavier the soil, the more bases are present—an important fact with relation especially to potash and lime. (3) The phosphoric acid, so far as any connection can be traced, varies not with the clay so much as with the organic matter. (4) A heavy soil may contain a considerable amount of calcium, even when free chalk is entirely absent, as in the case of the alluvium quoted. (5) But for the presence of ·38 per cent. of calcium carbonate in the Valley Gravel soil, the total amount of calcium base in this light soil would be comparatively small.

Biological Activity in the Soil.—There is still a very important feature of the soil which has not, up to the present, received more than passing mention, to wit, the life within it. A great variety of innumerable living organisms find their home in the soil. Some of the more obvious are rodents, earthworms, insects and myriapods (millipedes, etc.), all of which exert their effect on the composition of the soil, and, in particular, help to mix the decaying vegetation with the mineral particles. Besides these, however, there are many more lowly organisms, invisible to the naked eye, and indeed only just visible, many of them, under very powerful microscopes. Such are the soil bacteria. The existence of these and a good deal of the knowledge of their habits and importance have only been established by dint of much laborious investigation within the last 50 years.

Bacteria.—The search for the explanation of soil fertility has been going on for hundreds of years, but it was not until the middle of last century that the significance of the natural production and properties of those compounds of nitrogen which we know as "nitrates" began to be understood. It was Pasteur who suggested that the process of "nitrification" might be a biological one, that is, that it might be the result of the activities of some small organism. The process of sewage purification depended on this change, and investigators were struck by its comparative slowness in starting and by the fact that the addition of certain substances, such as chloroform, checked it. Other phenomena were observed,

notably that the chemical changes involved proceeded by more than one stage, but still no one had found the agent which brought them about. There followed an eager search in this direction, and in the years between 1870 and 1890 several groups of bacteria were isolated and identified as being the agents whereby the stages in which complex nitrogenous compounds, such as exist in decaying organic matter, are converted into nitrates. In addition, others were found leading a free existence in the soil, and still others living in the "nodules" found on the roots of leguminous plants such as beans and clovers, taking up the free nitrogen in the soil air and elaborating it into the complex organic compounds of their own bodies, thus increasing the reserve of nitrogen in the soil organic matter. There were still problems to be solved, however. There was evidence that some agency existed in the soil, which at times became distressingly apparent, for it was able to exercise a severe check on the numbers and the beneficial effects of these bacteria. Finally, a type of organism, much larger than bacteria, was discovered in the soil. This, also, was very numerous, and its existence and prosperity were seen to be inimical to the nitrifying organisms, a fact which to-day is recognized by the widely employed process of soil sterilization in intensive hot-house work. This practice encompasses the extermination of the Protozoa, as these predatory organisms are termed, after which the beneficial bacteria can multiply unmolested and restore or enhance the fertility of the soil so treated.

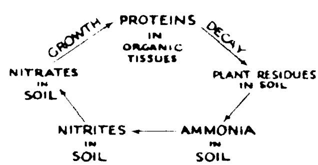
It is now possible to summarize our knowledge of this complex medium, the soil. It can be regarded as a very mixed assortment of mineral particles, of all sizes from obvious stones down to the ultramicroscopic clay, composed largely of silica, in its pure form, or in association with various bases, of which the most important are potash, lime, magnesia, soda and iron. Intermingled with these mineral particles is the humus derived from the residues of living organisms, especially plants, and made up of many complex organic compounds, some of which contain the valuable element nitrogen. There are also other inorganic substances disseminated through the mass, notably chalk (though not invariably) and calcium phosphate. The structure of the mass may be visualized as an association of the various soil particles into crumbs by virtue of their colloidal or jelly-like surface, consisting partly of the actual mineral matter of the particle and partly of humus. In and on the colloidal layer is the soil moisture, forming a finely dispersed but continuous medium throughout the soil and holding dissolved in it small quantities of the chemical constituents of the soil. To a varying extent, the interspaces are filled with air, providing the soil atmosphere, and upon the moist colloidal surfaces of the particles roam the organisms which have their existence thereon and collectively influence the fertility of the soil. It is on this material that the farmer exercises his skill and endeavours, by the use of tillage implements and manures, to produce and maintain in it a high level of fertility.

Nutrition of Plants.—Attention may now be paid to the growing plant to see what its requirements are and to what extent they can be supplied by the soil. Both the atmosphere and the soil play a part in the life processes of plants. To begin with, respiration is continually taking place just as in the case of animals, though in a much less obvious fashion. Some of the tissue of the plant is oxidized with the production of the necessary energy for life and growth. This is accompanied by the liberation of carbon dioxide and water, waste products which are got rid of by the leaves. In the daytime, however, and especially in bright sunlight, another vital phenomenon is apparent. This is the assimilation of carbon dioxide from the atmosphere, where it is always present in small amounts. On the under side of a leaf are found numerous pores or stomata, leading into small internal cavities lined by the walls of active living cells. The air containing carbon dioxide finds its way into these spaces and dissolves in the moisture in the cell walls. The green colouring matter in the cells, called chlorophyll, is able to utilize the energy of the sun's rays which fall upon it, to split up the compound carbon dioxide and build up the carbon so obtained into new substances of the nature of simple sugars. At the same time the oxygen which has been split off is set free and finds its way, *via* the stomata, into the air once more. It will be seen then that in the daytime a plant utilizes carbon dioxide from the atmosphere to build up its tissues more quickly than it produces that compound by respiration. The sugars produced are then distributed through the growing parts of the plant, and from them are elaborated many other compounds, mostly more complex, which play their part in the building up of its structure. Some of these compounds contain elements other than carbon, hydrogen and oxygen, the constituents of the sugars, and it is these which are obtained from the soil by means of the root system. The very fine root hairs which the growing plant is continually putting out to explore the soil for nutrient material, push their way amongst the soil particles and lie closely up against their wet colloidal surfaces. The soil solution or moisture in the soil diffuses through the membranous walls of the root hairs and along with it go small amounts of the various chemical substances present in it. The manner in which this happens is not fully understood, but there is no doubt about many of the facts connected with it, such as the enormous amount of water which a plant takes up, passes through its structure and respires from its leaves. There is no doubt, also, that the root system can absorb nutrients from the soil selectively, up to a point. The substances which are taken in from the soil in this way include nitrogen, phosphorus, potash, silica, iron, magnesium, calcium and others. They pass up into the structure of the plant and, together with the products of carbon assimilation from the leaves, form the materials from which all the various organic compounds comprising the tissues of the plant—proteins, carbohydrates, fats and oils—are produced. So for its growth a plant requires, in the main,

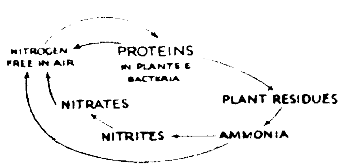
oxygen and carbon dioxide from the air, and water, nitrogen, phosphorus, potash and lime from the soil. Some idea of the quantities in which these substances are required is provided by the two following examples, one afforded by a cereal and the other a root crop. The former, if it yields 40 bushels of grain and 25 cwt. of straw per acre, removes from the soil 50 lb. of nitrogen, 20 lb. of phosphoric acid, 35 lb. of potash, and 10 lb. of lime, besides other constituents, and during its growth will transpire from its leaves 550 tons of water. A 25-ton crop of mangolds removes 85 lb. of nitrogen, 50 lb. of phosphoric acid, 250 lb. of potash, 25 lb. of lime, etc., and will transpire 900 tons of water during its period of growth. These figures indicate that the biggest demand on the part of a growing crop is for an adequate supply of water, without which no additions of other plant nutrients can exert anything like their full effect. It is an interesting arithmetical study to see what this means when put against the existing rainfall. One inch of rain on an acre gives 100 tons of water, so that for a successful barley crop, the water equivalent to 5½ in. of rain must be actually supplied by the soil and transpired through the plant, which occupies the ground from March to August. In the eastern counties the average rainfall is about 25 in., of which 8 in. will usually fall within the period mentioned. So that it will be readily seen that the physical properties of the soil and the success of the cultivations designed to conserve the moisture in the soil will have a much more potent effect on the barley crop than the various chemical compounds concerned as nutrients, especially when it is remembered that evaporation of water from the surface of the soil is taking place continually, while rainfall is spasmodic.

Availability of Nutrients.—Although of secondary importance, however, the other plant nutrients are well worth study. The utility of fertilizers is, nowadays, demonstrated beyond doubt by the huge dimensions of the fertilizer trade, and most people are personally acquainted with instances of marked responses by crops to their application. Yet when the increases in crop produced, the amount of added fertilizer, the amount of the particular constituent removed by the crop, and the amount of it present in the soil are all considered together, no very obvious connection is apparent. The average arable soil contains about ·2 per cent. of nitrogen, which, in a acre of soil 9 in. deep, represents 5,000 lb., an amount enough to supply this constituent for as many bushels of grain. But the roots of wheat, for instance, in their search for plant food, go much deeper, so that they come into contact with an even greater amount of nitrogen, probably not exaggerated if put at 10,000 lb. per acre. In spite of this, it is found that the average yield of wheat on the classic unmanured plot at Rothamsted, containing an amount of nitrogen of this same order, is steady at about 12 bushels per acre. On a neighbouring plot, receiving anually 40 lb. of nitrogen in the form of concentrated fertilizer, an equally steady average yield of 22 bushels per acre is maintained. This would suggest that

the total amount of nitrogen has little direct bearing on the size of crop grown, but that there is probably a factor of great importance in the form in which the plant can assimilate it. If a similar rough calculation is made of the amount of nitrogen present in the soil in forms similar to nitrate of soda and sulphate of ammonia, the figures obtained take on a more ordered aspect. There are found in the soil at different periods of the season varying amounts of nitrates and ammonia, two comparatively simple compounds of nitrogen, of the order of ·0005 per cent. and ·000025 per cent. respectively. These represent, per acre, a total of 16 lb. at any moment. This figure is substantially of the same order as the amount of nitrogen in the fertilizer dressings referred to above, so that there is strong support for the view that the amount of nitrogen present in the soil in an assimilable form, *e.g.*, as nitrate, has a direct bearing on the crop yield. As has already been indicated, the bulk of the nitrogen present in the soil is in the form of complex protein-like compounds in the humus or organic matter, and that these are constantly being broken down into simpler compounds by the action of specific bacteria, until they result in the production of ammonia which, in its turn, is converted into nitrate. The organic nitrogenous compounds are mostly insoluble and certainly not able to be absorbed into the root system, while ammonia and nitrate are comparatively simple in composition, readily soluble in water, and easily assimilated by root hairs. This sequence of changes forms part of what is known as "the nitrogen cycle," or the way in which the element nitrogen is continually in circulation in nature. Most of the stages in this cycle have already been indicated in different connections, but it is convenient here to view it as a separate phenomenon. In its simplest form it can be set out as follows—



—to illustrate the continuous growth and decay of plants. But the activities of bacteria and the processes of decay are not merely the mechanism of this simple cycle ; they have trends of their own leading in other directions, as indicated in the following version :—



Some of the nitrogen of the proteins is set free and added to the store already existing in the atmosphere, while some of that in the

nitrates produced in the soil suffers a similar fate. On the other hand, several different bacteria can feed on the free nitrogen of the air and elaborate it into proteins in their own bodies. Sufficient has been said, perhaps, to indicate the respective influences of proteins and nitrates, to mention the two most important stages of the cycle, upon the fertility of the soil and the growth of plants. The proteins constitute the reserve in the soil, the material from which a constant supply of easily assimilable nitrates is produced. The rate of this production depends on the temperature, moisture and aeration of the soil. It is at a low level during the winter months, but as soon as the soil warms up in spring, it rises rapidly, with the result that the amount of nitrate found in fallow land constantly increases until September, when production falls off and drainage commences once more, gradually reducing the amount to its winter minimum. In the case of land under a crop, the nitrate is continuously absorbed, with the result that the amounts found reach their maximum in June, then fall off steadily until August, rise again to an autumn maximum in October, and then again decline to the winter level. It will be understood from this brief outline, that easily soluble nitrogenous compounds used as top dressings in the early spring, before nitrification is really active, are in a position to exert a very potent influence on the growth of a crop in its early stages. It also follows that the effect of such fertilizers is exerted within a short time of their application and that they are unlikely to have a permanent effect in raising the fertility of soil. But there are many materials of undoubted value as manures which in themselves are more of the nature of proteins. All the organic refuses come into this category, so that their use produces rather different effects. They do, in fact, increase the reserve of nitrogen in the soil at the same time as they add some of it in a condition in which it easily progresses through the cycle, *i.e.*, is soon converted into nitrates. The users of this class of fertilizer generally make it a practice to add supplies regularly to the soil, thus steadily enhancing its fertility and ensuring that when the nitrification processes are active, the amounts of nitrate produced may be correspondingly increased all through the season. This kind of treatment is much more essential for some crops than a liberal supply of available nitrogen given early in the growing season, as in the case of quick-acting top dressings.

The consideration of nitrogen as a plant nutrient and the relations between the store present in the soil and the amount actually absorbed by the plant has served to illustrate what is meant by the term "available plant food." This is an expression frequently employed in technical phraseology with regard to the nutrition of plants, to call attention to the fact that it is not so much the total amount of any one constituent which matters as the extent to which that constituent is in a form assimilable by the plant roots, or, in other words, how much of it is available. In the case of nitrogen there are a number of established facts, as indicated above,

which enable a fairly clear idea of the position in the soil to be obtained. In the case of those other important nutrients, the mineral constituents, especially phosphates, potash and lime, our knowledge is not quite so satisfactory. Looking at them on the same simple of quantitative basis, it is found that a common figure for the amount phosphoric acid in a soil is ·1 per cent., which, by calculations similar to those employed in the case of nitrogen, represents over 5,000 lb. within root range, and yet by the addition of two or three cwt. of superphosphate, containing about 40 lb., remarkable effects on the crop are frequently obtained. In the case of potash, a much greater range of total content in the soil is experienced, from ·1 per cent. or less in light, sandy soils to over 1 per cent. in heavy clays, representing from 5,000 to 50,000 lb. per acre within root range, but again, when the soil responds to applications of this constituent, it does so to dressings containing amounts of the order of 40 lb. per acre. It has been shown already that the phosphoric acid in the soil is present partly as mineral matter, calcium phosphate, and partly as a constituent of the organic matter. The potash is there as a constituent of the original minerals or of their partly weathered residues. In the soils of the south-eastern half of England it occurs chiefly in the smaller particles, particularly in the clay fraction, so that the total amount increases with the heaviness of the soil. That all these compounds, whether phosphate or potash, are practically insoluble in water is evidenced by the very small amounts which are found in drainage water or in the soil solution.

At the same time there is evidence that in some soils the phosphate is more "available" to the plants than in others. It is possible to find instances of soils containing the higher amounts of total phosphate which respond to added phosphatic fertilizers, while others with a lower total content show no response. Phenomena of this kind have led to the view that there are differences in the state or constitution of the phosphates in soils, making them more or less easily assimilable by plant roots. It was also suggested that the root systems excreted acid juices which could dissolve the mineral nutrients, phosphate and potash, and so render them useful to the plant. After a period of experiment, Dyer came to the conclusion that this action of the roots could be very closely imitated in a laboratory by shaking up the soil with a 1 per cent. solution of citric acid under certain standard conditions. By means of this test he was able to differentiate between soils with respect to the amounts of "available phosphate" and "available potash" which they contained. His results agreed fairly well with the actual response of the soils in the field to added fertilizers, and to this day his method is widely employed by advisory chemists to assess the need of soils for these particular constituents. Such practitioners, by dint of accumulated local experience and data from the soils with which they are familiar, are able to set up in their own localities certain standard limits about which they can dogmatize with a fair degree of accuracy. For instance, in some

areas, available phosphoric acid below ·01 per cent. is considered to be deficient and over ·02 per cent. to be adequate, and, as a rule, the response of the soils to added phosphate will be in accordance with these tenets. Similarly ·007 and ·014 per cent. might be the corresponding limits for potash. It is obvious that such standards cannot be regarded as hard and fast, but, due consideration being given to other known facts, such as the history of the field and the behaviour of the crops on it, this form of analysis is a valuable aid to a correct diagnosis. A useful modification of the method consists in studying the ratio of the "available" to the "total" amount of either constituent instead of the absolute percentage. The following examples are from different fields on one farm.

	1	2	3	4	5	6	7	8
Total phosphoric acid %	·123	·092	·139	·083	·119	·116	·078	·243
Available ,, ,, %	·013	·011	·010	·025	·033	·031	·017	·016
Available as % of total	11	13	7	30	28	27	22	7
Total potash % ...	·248	·332	·260	·147	·115	·164	·206	·492
Available ,, % ...	·016	·012	·009	·023	·007	·005	·007	·017
Available as % of total	7	4	3	15	6	3	3	3

Numbers 1, 2, 3 and 8, by this criterion, seemed to be short of available phosphate; in practice they were the fields where phosphatic fertilizers produced the bigger response. There is not such a marked contrast in the case of the potash. On the ratio of available to total potash, they all look poor except number 4, while in practice numbers 3, 5, 6 and 7 gave the best results for the use of potash.

It is difficult to define or explain this "availability" of plant nutrients, although different workers have attacked the problem from many angles. It is 200 years since that pioneer Jethro Tull expounded his views on the subject, and they bear a very close resemblance to some of those expressed by eminent soil scientists of the present day. He realized the tremendous importance of tilth in making a soil productive, and the connection between it and the internal surface area of the soil. He regarded this as the "pasture" area of the soil so far as plant roots were concerned, and devoted all his energies to the improvement of tillage implements in order to keep this area at its maximum. In his day little was known of the chemistry of the soil or of plant nutrition. He was convinced that an important part, if not all, of the necessary nutrients resided on the surface of the soil particles, and so argued that the more of this surface there was made accessible to the searching roots, the more nutriment the plant would obtain. Enough has already been said in the present account concerning the soil solution and the action of plant roots on the colloidal surface of the particles to show that his line of reasoning had very much the same trend as that of subsequent workers. It must be remembered that the need for, or the effect of, such constituents as phosphoric acid or potash in soils is, to a great extent, determined by a number of circumstances which render it difficult to state anything in the nature of standard

requirements. For instance, the amount of phosphoric acid required in the case of a heavy soil may be greater because its function in developing a vigorous root system is more important for the crop than it otherwise need be, on account of the greater resistance offered by more sticky soil to the movement of growing root hairs. Or, in conditions of insufficient water supply, a correspondingly larger root system may be necessary to the plant in order that it may more thoroughly search the soil to obtain its due supply. Further, the bases with which the phosphoric acid is associated may influence the ease with which the plant can assimilate what it needs ; the value of the phosphates of iron and aluminium, as compared with those of calcium, is not necessarily the same. In the case of potash, it has been clearly demonstrated that the need for it is very definitely connected with the amount of rainfall during any season, and so with the moisture content of the soil.

Other methods of assessing the availability of the mineral plant foods in a given soil have been tried out by investigators in recent years, especially on the Continent, by a more direct appeal to the plant, instead of by soil analysis. On the grounds that a single nutrient factor, such as phosphoric acid, exerts a specific effect on the crop, as evidenced by the yield, attempts have been made by studying the yields obtained by varying additions of a single manurial constituent, to calculate the amount of this originally present in the soil. This method has been severely criticized because of the difficulty of isolating the effect of a single factor where so many are obviously concerned. This drawback, coupled with the slow and laborious nature of the investigation, precludes its general adoption. There are, however, investigational methods which are more rapid and more easily carried out which have attained a certain measure of success. That of Neubauer is an example. This worker relies on the ability of seedlings, given favourable circumstances, to extract all the available plant food in a given sample of a soil within a comparatively short time. His procedure is somewhat on the following lines. He mixes a small quantity of his soil sample with about three times its weight of pure sand, sets it up in saucers, plants in each 100 seeds of rye or barley, and keeps the whole at carefully regulated conditions of temperature and water supply for 17 days. At the end of this period the seedlings are lifted, carefully washed free of soil, dried, and analysed for their content of phosphate, potash, etc. The figures obtained are then used to determine the sufficiency or lack of any individual constituent in the particular soil under experiment. This line of attack has been much used, since its discovery, by the fertilizer interests in Germany, in connection with field investigations and for routine advisory purposes.

Reaction and Lime Status.—There still remains to be considered one constituent of the soil which ranks as a very important food nutrient but which is the more indispensable because of its effect on the condition and fertility of the soil. This is " lime," or

the calcium base, which is absorbed by plants along with its other food material, but which also has a dual effect on the soil in improving its texture and in keeping its reaction sweet and suitable as an environment for most of our useful crops and for the beneficial micro-organisms which so greatly influence fertility. In ordinary parlance, we find soils described as being in a sweet, sour, or, in some parts of the world, alkaline condition. Before attempting to explain the causes of these variations, attention may be called to some of the effects of the particular phase which causes most trouble in this country. Many readers will have noticed at some time or other an ordinary short ley of rye grass and clover in which there were patches where the clover was conspicuous by its absence, while the rye grass was growing strongly. This is frequently the result of sourness. It may be useful to describe a particular case, encountered in 1927. The late summer of that year, in the locality where this example occurred, was very wet, so that the second cut was not mown. The clovers ripened off, with the result that the field showed up brown in colour, owing to the withered blooms of the clover. But it was splashed with various-sized patches of rich green, where only the rye grass was growing. Samples of soil were taken from several of the green patches and also from adjacent brown areas, and were examined individually in the laboratory. In the routine which is followed in these cases, the first things noticed were that in the samples from the rye grass patches there were no visible particles of white chalk, as there were in most of those from the normal areas, while, on drying, the former set in hard lumps, while the latter crumbled easily. The difference in the total chalk present was confirmed by analysis. When the reaction of the soil was tested by indicators, such as litmus paper, the rye-grass patches were found in every case to be acid. Finally, the various samples were shaken up with a solution containing chalk, to see how much of this substance each one would absorb, a process known as a "lime requirement determination." It was found that the rye grass patches took up appreciable amounts. It is unnecessary to go into the technical details of these chemical investigations, but the above short description of the procedure, coupled with the figures obtained, provides a useful basis on which to discuss this subject.

Condition of Crop.	Worst Failures of Clover.	Bad Clover Failure.	Good Mixture of Clover and Rye-grass.	Biggest Mixed Growth.
Visible chalk ...	0	0	Moderate amount	Moderate amount
% Total chalk ...	·02	·05	·31	·59
Texture on drying	Hard clods	Hard clods	Crumbled easily	Crumbled easily
Reaction by indicator ...	Acid	Acid	Doubtful	Neutral
% Lime requirement or chalk absorbed ...	·166	·075	0	0
Lime requirement as cwts. per acre 9 in. deep ...	40	18	0	0

A perusual of these results indicates a definite connection between the prosperity of the clover plant, the tilth of the soil, the amount of the soil's reserve of chalk, its reaction, and its need for "lime." *It would also appear that rye grass is able to withstand a condition of sourness, or lack of "lime," which is inhibitive to red clover. The connection goes further, as was evidenced on this field in the following year, when it came into wheat.* The same cloverless patches showed up as areas of a sparse wheat plant, associated with a marked abundance of weeds. This is not altogether surprising when one recollects the value of a clover ley as a precursor to wheat.

Lime Content.—In describing the chemical composition of the soil, it was shown that calcium compounds of various kinds are present. Many of the particles contain unweathered and partially weathered minerals containing the calcium base among others. It is present also as free calcium carbonate, often in the form of chalk or limestone fragments, and as calcium phosphate. Reference may be made to the table on p. 20, when it will be seen that in many heavy English soils there may be found a greater amount of calcium base, even in the complete absence of "chalk," than in adjacent light soils containing an appreciable though small reserve of that substance. This is an important point which goes a long way towards explaining why, on many heavy soils devoid of free calcium carbonate, a dressing of lime produces no response. In soils containing a reserve of this form of calcium, there is a great variation in the amount present, as is shown by the figures for a number of soils in Berkshire set out below, from which it will be seen that there is a connection between this point and the parent rock from which the soil is derived :—

Geological Formation.	No. of Samples examined.	% Calcium Carbonate Present.
Valley Gravel	12	0–1
Clay with Flints, on Chalk	14	0–9
Plateau Gravel	7	0–·18
Bagshot Beds	6	0–·2
London Clay	14	·02–1·5
Chalk	26	10–70
Upper Greensand... ...	6	·02–1·4
Gault	6	·5–11
Kimeridge Clay	4	·12–·7
Lower Greensand ...	3	0–·1
Coral Rag	6	·9–39
Oxford Clay	8	0–2·4

Attempts have been made to prescribe a figure for the amount of chalk necessary to keep the soil healthy in reaction and adequately supplied with calcium base, but it is difficult to do this owing to the fact that it performs various functions. In heavy

soils it has a good deal to do with keeping the clay fraction in a satisfactory state of tilth, and, accordingly, it eases tillage operations to a considerable extent, while in all soils it counteracts acidity and provides a valuable plant nutrient. Some light soils, by virtue of their favourable topographical situation, are kept suitably supplied by chalk-bearing underground water. Normally, *free chalk to the extent of ·1 per cent. will supply the needs of light soils, but as their level of fertility is raised, this amount may prove insufficient, as, for instance, in intensive cultivation coupled with the use of liberal additions of manures, when ·2 and ·3 per cent. may be found necessary.* Heavy soils, on the other hand, when more intensively worked, will sometimes show the benefit of a reserve rising to the neighbourhood of 1 per cent. Furthermore, the problem is complicated by the varying degrees of tolerance which different crops exhibit towards an acid reaction in the soil.

Signs of Acidity.—So far as observation in England goes, crops such as rhubarb, rye, potatoes, oats, swedes, alsike and kale will tolerate definite degrees of acidity, while clovers, mangolds, sugar beet, peas, beans and barley will frequently fail under the same conditions. Amongst the grasses, cocksfoot, sweet vernal, sheep's fescue and Yorkshire fog fall in the former group, while foxtail ranks with the latter. Similarly amongst the weeds of arable land, sheep's sorrel, spurrey, corn marigold and mayweed will flourish on acid soils. The first three, indeed, when present in quantity, are an almost infallible sign of sourness. The more lowly forms of life, such as fungi and bacteria, also show preferences as to the reaction in which they flourish. For example, the fungus causing Potato Scab does not tolerate acidity, as its host does, and so appears most frequently when the soil is limed. The organism causing Finger and Toe or Club Root, a trouble prone to be widespread on all Cruciferous crops, is most virulent in acid conditions (p. 363).

These various points serve as good indications of the occurrence of sourness, but it should be borne in mind that no single one constitutes definite evidence. Inspection of the soil is often sufficient to indicate the absence of any reserve of calcium base in the shape of chalk particles, and if this is associated with such phenomena as the existence of a pan, leaching of the soil, formation of matted turf at the surface, together with crop and weed indications of the type detailed above, the diagnosis is tolerably certain to prove correct. This condition of acidity may be due to several and varied causes. A deficiency of calcium base in the original minerals from which the soil was derived may lie at the root of the matter, or it may be that the weathering processes have leached away the calcium of the original minerals, as in the case of some of the lighter sandy soils of our more recent geological formations. At the same time the growth of vegetation on the soil may have resulted in the accumulation of a layer of sour, partially decayed organic matter,

such as occurs in peat or matted grassland. This substantially aggravates the state of acidity in the soil though it may be itself regarded as due to that condition. Finally, man's own operations of cropping and manuring may be such as to consume the chalk reserve and lead to acidity. This happens occasionally where intensive farming is carried on without the use of lime, or where ammonium salts are constantly used for top dressings, or where crops are continuously taken from the land without adequate manuring.

The cure for acidity in soils in this country is, of course, liming, but as this is an operation which entails considerable expenditure, some 30s. or more per acre, it is as well to go to some pains to get as certain a diagnosis of the condition of any fields under consideration as is possible. Enough has been said to show that, as a rule, the signs of acidity are very definite ; they are a much better guide than the effervescence produced on pouring acid on a small quantity of the soil, a rough and ready test which really only shows when adequate reserves of chalk are present, and is not very helpful in doubtful cases. It is advisable, when in doubt, to call in the aid of the county organizer, who can have the soil chemically examined and so obtain definite quantitative information on the condition of the soil. There are also on the market useful soil indicators which are of great value in sorting out the fields on any given area of soil, but a certain amount of practise is necessary in their use, and again they should be followed by critical chemical examination. It will be seen also, from the preceding account, that it is possible to introduce modifications in manurial practice and in the type of crops grown so as to meet the difficulty in fields short of the calcium base or possessing only a small reserve of lime. Thus potatoes, swedes, rye, oats and alsike will, other things being equal, fare better than turnips, mangolds, sugar beet, barley and clovers. Cyanamide, nitro-chalk, and nitrate of lime will be safer forms of nitrogen than ammonium salts, and may even give better results. Carrying, as they do, their own supply of calcium base, the first-named in particular having a definite content of free lime, they will make less call upon and eke out the scanty reserves of any soil in an acid condition. Among the phosphatic fertilizers there is point in employing basic slag, mineral phosphate or bone meal in preference to soluble phosphates such as superphosphate, dissolved bones or ammonium phosphate.

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CHAPTER II.

FARM IMPLEMENTS.

THE first implement of tillage is the plough. With this a layer of soil, usually between 4 and 8 in. in depth, is separated from the underlying subsoil and inverted, any manure or vegetation on the surface being buried. The soil moved is laid in long seams or furrow slices, which may either be set up on edge so that a large area is exposed to the effects of the weather, or may be considerably broken up in the process. Pulverisation is effected by other implements: the cultivator breaks up the furrow slice, harrows stir the soil, level it, and break down the lumps, and rollers crush clods. The condition of tilth to be aimed at varies widely according to the season of the year, to the soil, and to the crop for which the soil is being prepared, but the general object is to work the soil until it is reduced to a fairly fine state of comminution. In this state mould is available at the surface for covering the seed evenly, and the total area of the soil particles available to the root hairs is greatly increased. The working leaves the soil in an open enough condition to allow of the easy penetration of plant roots, but it must be fairly firm to give a good roothold.

The art of cultivation lies in using implements to the best advantage, so that full benefit may be derived from the disintegrating effects of frost, wetting and drying, and changes of temperature, and so that the optimum conditions of tilth may be obtained with the minimum expenditure of energy. This art can only be mastered by experience, but a first step in its acquisition is a realisation of the purposes for which particular implements are constructed, and the principles of their action.

There are certain properties which are required in all farm implements, quite apart from their efficiency in the work for which they are constructed. It is important that an implement should be strong and yet light; in this respect great improvements have been made in the past as better materials have become available, but there is still room for advance. Skill in design may do much in reducing the draught of an implement, and minimum draught consistent with good work is an important desideratum. It must be remembered that farm labourers, though generally skilful with implements, are not trained mechanics, so that an implement should be simple both to work and in its running repairs. It is important that an implement should be able to pass through a 9-ft. gateway, either in its working state or with little and rapidly executed change. The price of the implement and the cost of its maintenance are items of obvious importance.

Ploughs.—The plough of to-day is the result of many centuries of experience. Its primitive prototype was probably no more than a pointed stick. Its form slowly developed until the heavy wooden plough of the seventeenth century was reached. The latter was very clumsy and of very heavy draught, but it performed what is

now regarded as the distinctive action of the plough in that it inverted the soil. From thence evolution has proceeded to an iron plough of considerably less weight and much greater efficiency. Progress has been slow, but the principles involved in the construction of a plough are not simple, and it is not to be supposed that finality has yet been reached. One factor which impeded progress in early times was the very localised existence of the types produced. Latterly large firms have sprung into being, which have tended to standardise the implement. Nevertheless, there are a variety of types available to-day, and certain of these still enjoy special popularity in particular districts, either because of soil peculiarities, or more probably as a result of old custom and prejudice yet lingering on. This applies, to a certain extent, to all implements.

The common ploughs of to-day fall fairly definitely into two types—the general purpose plough and the digger: some are intermediate in form, but a description of these two suffices to show the principles involved.

THE GENERAL PURPOSE PLOUGH. The parts of the plough are shown in Figs. 2 and 3. The draught chain, by which it is pulled, fits into any one of a series of notches in a vertical plane in the hake, which itself can move over a horizontal arc (the quadrant)

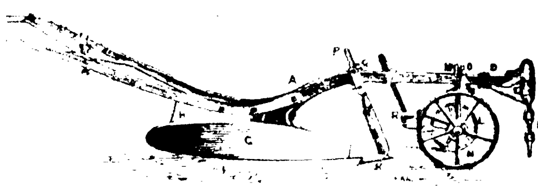


FIG. 2. SINGLE-FURROW PLOUGH

A, beam.
B, handle or stilts.
C, handle stay or brace.
D, quadrant head.
[illegible] sliding head.
[illegible] draught chain.
H, [illegible] mould-board.
[illegible], h[illegible]

K, share.
L, land wheel.
M, land-wheel stan[illegible]
N, furrow wheel.
O, furrow-wheel st[illegible]
P, coulter.
Q, coulter clip.
R, skim-coulter.

on the fore end of the beam. Thus the point at which the [illegible] applied can be varied in both directions, with great effect [illegible] running of the plough (see below). In some designs the hake [illegible] the form of a vertical iron rod, which can be raised or lowered on loosening a nut where it passes through the sliding head of the quadrant.

Just behind the quadrant the beam carries a cross bar be[illegible] the wheels. The larger of these runs in the furrow against the [illegible] face cut by the coulter during the previous passage of the pl[illegible] whilst the smaller one runs on the unploughed land. Bein[illegible]

wheels a clip fastens the coulter to the beam. The coulter is knife-edged in front, and its function is to make the vertical cut in detaching the furrow slice (Fig. 7). On some ploughs the coulter takes the form of a large steel disc, which rolls along the surface cutting for a depth of 1 to 2 in. This form is very efficient in cutting

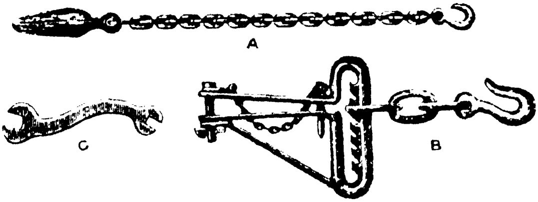


FIG. 3. PARTS OF PLOUGH.
A, drag weight and chain. B, hake and chain.
C, spanner.

turf or any vegetable matter lying on the surface, and as its circular motion tends to clear it of rubbish it is commonly used with tractor ploughs. At the rear of the beam are affixed two handles or stilts, by means of which the ploughman controls the implement.

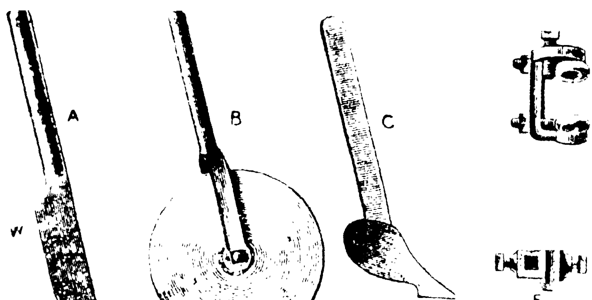


FIG. 4. PARTS OF PLOUGH.
A, coulter (W, hole for attaching drag weight and chain, Fig. 3, A). B, disc-coulter. C, skim coulter. D, coulter clip and loops. E, wheel socket and set screws.

The body, which carries all the working parts except the coulter, is bolted on to the beam near its rear end. It has a steel plate (the slade) fixed to its under side, on which it slides along the furrow bottom, and another (the land-side) which bears against the face cut by the coulter. These two plates are detachable and in some designs are in one piece.

The share, whose purpose is to make the horizontal cut in separating the furrow slice from below, fits on to a neck on the foremost point of the body. If the share were to cut the full width the slice would tend merely to be pushed sideways by the mould-board.

This is avoided by using shares which leave an inch or so of soil uncut on the furrow side, which, before it is torn away, suffices to prevent lateral movement of the slice long enough to give it the rotating movement which leads to its inversion. Plough shares are of various shapes (Fig. 5) ; in some the cutting face is nearly at right-angles to the line of draught, but where the land is stony this face must slope back steeply or wear will be very rapid. All shares for the general purpose plough have a definite neck ; this

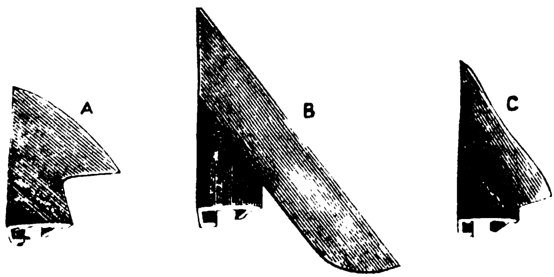


FIG. 5.—FORMS OF PLOUGHSHARES.

A, *for square work in loams and land free from stones.* B, *paring share for skimming stubbles.* C, *pointed share for stony land.*

causes the wing, with its cutting edge, to be advanced well in front of the mould-board; thus the cut is made far enough ahead to prevent any tearing action being caused by the soil rising on the mould-board, which would have the effect of breaking the slice. Plough shares are cheap and very easily detachable—they are only held on by the forward thrust of the implement ; on stony land they may only last for three days or even less, but they will survive for much longer periods on other soils. They are made of cast iron chilled on the under side, which therefore wears more slowly than the top side, and consequently they keep a sharp edge throughout their life.

Much thought and ingenuity have been devoted to the fashioning of the mould-board (Fig. 6). The furrow slice is rotated through an angle of roughly 135° but its motion is by no means simple, for it rotates about its lower right corner for the first 90°, and then about its original upper right corner, when that point comes in contact with the bottom of the furrow. Its centre of gravity can be shown to rise during the first 55° of its rotation, to fall during the next 35°, to rise for the following 35°, and to fall again slightly during the last 10°. If the slice is to be turned unbroken the mould-board must be in contact with it throughout, and this is found to necessitate a form in which the twist is gradually increased for the first 55° and thereafter diminished ; the mould-board must also be convex (*i.e.*, from top to bottom) throughout its length, or crumbling will be caused. In the case of ploughs used in competitions the mould-board may be nearly four feet long, the object

being to turn the slice over slowly and press it gently into place against the previous one. At least one-third of the draught of the plough is due to friction of the soil on the mould-board; this is largely affected by the amount of moisture present, and it has been

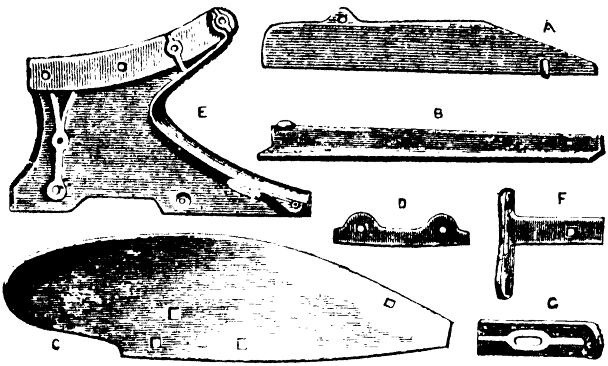


FIG. 6.—PARTS OF PLOUGH.

A, side-cap, or land-cap.
B, slade.
C, breast; D, its rest, or "footing."
E, cast frame, or body.
F, frame coupling.
G, breast coupling.

suggested that the work might be lessened by passing an electric current through the implement to give a deposit of water on the mould-board to act as a lubricant.

Two other fittings are supplied with ploughs for use where much surface material has to be buried; these are the skim coulter and the drag-weight and chain (Fig 3.) The skim coulter is itself a diminutive plough, which runs a few inches in front of the knife coulter, turning a very small furrow of about 1 in. depth from the left hand side of the furrow slice to the right; the vegetation thus moved is deposited at the bottom of the furrow, when the main slice is turned, instead of protruding between two slices as it is apt to do where no skim coulter is used. The other fitting consists of a two foot chain attached to the coulter, its other end bearing a bullet-shaped weight, which lies in the furrow when the plough is at rest; as the plough moves forward the chain is being continually dragged over the surface of the furrow slice as the latter turns, and the action is very effective in getting anything on the surface completely buried.

SETTING THE PLOUGH.—There are many adjustments possible on the plough to meet varying conditions of soil and requirements of work. The share plays a large part in holding the implement into its work. For this purpose it is given a slight pitch in two directions—downwards and towards the land side; that is to say, if a rod be laid from the point of the share to the heel of the slade there will be a slight clearance between it and the implement throughout its length, and similarly on the land side of the plough. This

creates a suction which holds the plough down and toward the unploughed land, but it must not be over accentuated or the point of the share will keep digging in, and the plough will run badly with an increase of draught. Ploughs are made in which pitch may easily be given to the share at will, but often it has to be obtained by putting a little packing (often paper) inside the neck of the share. The coulter should be set straight or it may be given a slight inclination toward the land side and its point should be as far forward as the point of the share, otherwise the latter will have to lift a slice not yet cut from the land ; the coulter should be very slightly wider than the point of the share, because pressure will tend to bend it inwards, and a clearance of an inch or so is commonly left above the share, especially on stony ground. In soft soil without much rubbish on the surface the coulter may be nearly vertical, but where there is much vegetable matter it is better to have its top tilted backwards at an angle of about 35°, as then the rubbish will run up it and clear better ; if tilted in this way it will also tend to hold the plough in, as it is being continually drawn downwards.

The hake and quadrant are also intimately connected with the depth and width of working. Raising the chain in the hake has the effect of making the plough run deeper, as also do long chains on the horses, for the best results a plane drawn through the hooks on the horses' collars and the point of attachment at the hake should, if continued backward, cut the mould-board a little above the share, for there is the centre of resistance. As regards the quadrant it can easily be seen that moving it to the right tends to make the plough run to the left and vice versa.

Finally the wheels have to be considered. The depth of ploughing is the height of the bottom of the land wheel above the bottom of the furrow wheel, and the latter should be placed just far enough laterally to run lightly against the vertical face of the furrow. No stress should be placed on the wheels when the plough is moving, as such can only mean loss of efficiency ; the correct running should be obtained by the other adjustments and then the wheels should be set to run easily and lightly, their function being merely to steady the implement. If the plough be well set it should need very little, if any, steadying by the ploughman, except in hard or stony ground.

FORM OF THE FURROW SLICE. The object of the long mould-board of the general purpose plough is to turn intact furrow slices and to set them on edge. In this way a large and a new surface is exposed to the action of the weather, and spaces are left below into which water can drain from the surface, and along which drainage is also possible ; setting slices on edge also leaves the field in good condition for broadcasting seed, as the latter falls between the slices and can easily be covered by cross harrowing. It is obvious that if a furrow slice is to be inverted its width must be greater than its depth, for, if these be equal, when it has been rotated through 90° its original vertical face will just fill the open furrow left by the previous slice ; if the width be greater it will fall

down on to the previous one, and in this movement its inversion is completed. Where it is required to set the furrow slices up at an angle of 45° to the horizontal (a very common aim) the ratio between the width and the depth should be 10 : 7 ; if the width be relatively less the slices will stand more upright—which may be desirable in winter ploughing to get the full benefit of drainage and weathering —whilst if it be greater they will be laid more flat.

In general furrow slices are rectangular in cross section, as must necessarily be the case when the coulter and the share are at right angles to each other. In the past it has been much argued that a so-called " crested " slice is preferable ; this form is obtained by having the wing of the share pointing upwards so that the angle between the cuts of the coulter and the share is acute ; this leaves the top of the unploughed subsoil irregular (Fig. 7, 2), though the advantage of this is doubtful. It can be shown that the crested slice exposes about 10 per cent. more surface to the action

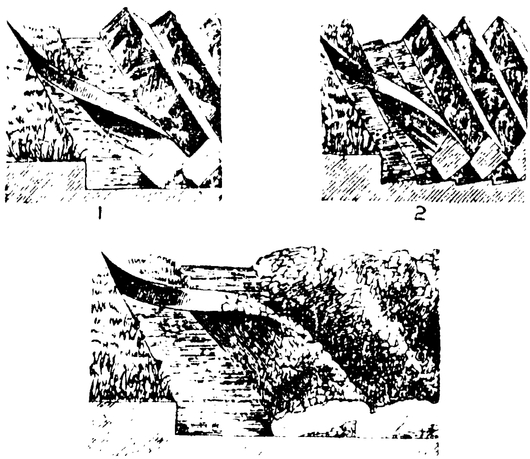


FIG. OF FURROWS.

(1) Rectangular furrow, unbroken ; (2) crested furrow, unbroken ; (3) wide furrow, broken.

of the weather, and gives rather better conditions for broadcasting; on the other hand, the ratio between the width and the depth (at its deepest) of the furrow slice is reduced to less than 9 : 7, and consequently the rate of ploughing is reduced by something over 10 per cent.

THE DIGGING PLOUGH. The long mould-board plough described above is more particularly adapted to autumn and winter work, or to the ploughing of fallows where the object is to keep the land cloddy. When ploughing in spring for spring sown crops weathering cannot be depended on to play a very large part as

time is limited and severe frosts are not to be expected : in that case therefore, it would clearly be an economy to use a plough designed not only to invert the soil but also to pulverise it considerably. Such an implement is the digging plough.

The mould-board of the digger is short, concave, and has a rapid twist ; the share is short and has no neck, and the coulter is often not used, the front of the body being sharp and capable of making the vertical cut. Its action is very different from that of the general purpose plough : the furrow slice is torn from its place, raised rapidly on the mould-board and given a sudden twist which bends it on itself and finally throws it down against the previous one. All this tends to considerable pulverisation, which in the case of some diggers is further increased by knives fitted at the rear of the mould-board. Because of the disintegration of the slice there is not any necessity to maintain any definite ratio between the width and the depth of ploughing with a digger ; in practice considerably wider furrows are taken with consequent economy of time.

The digger is often used without wheels—the term "swing plough" is used to describe all wheelless ploughs—but some skill is required in managing it in that case. In order to make its control possible when used as a swing plough the beam is shorter and the stilts are longer than with the general purpose type, because this gives less leverage to the horses and more to the ploughman.

METHOD OF PLOUGHING.—Common ploughs only turn a furrow one way (to the right), and thus with them it is impossible to plough a field by starting along one side and working backwards and forwards until the other side is reached. The method commonly adopted is to draw a series of ridges across the field, their distance apart being usually 22 yards, though they are often put nearer together on heavy land. In setting up a ridge it is too common merely to turn a furrow over and, on the return journey, to turn another against it from the opposite side ; if this is done there is a strip of soil in the middle of the ridge which is never moved at all. The correct method is to turn a shallow slice over and on the return journey to turn the adjacent strip in the opposite direction, thus leaving a double open furrow : on the next two passages across the field these two slices and the strips of soil on which they lie are turned together into this open furrow to form the ridge.

The ridge having been set out the procedure is to work round it, turning slices towards it from each side ; this is called "gathering," and it is continued until 5½ yards width has been done on each side. Next 5½ yards width is gathered on each side of the second ridge. This leaves a strip 11 yards wide between the two ploughed pieces, and the next step is to work round and round this turning the furrow slices outwards ; this is called "casting" or "splitting" and is continued until the space between the two ridges is finished, leaving a double open furrow midway between the two ridges.

The open furrow is generally left as it is formed when the last of the land has been moved, but sometimes another furrow is ploughed out of its bottom, thus making it more efficient as a surface drain. Another practice is to "plough back"—that is, one (or possibly two) small furrows are turned from the side into the open furrow—with the object of leaving the field more even; the practice is rare, but it makes the surface better for the binder at harvest, and some farmers make a point of a level surface at the last ploughing before laying down to grass.

The first land having been completed with the double furrow, a third ridge is started and the gathering round it, and the splitting between it and the second ridge, done as before, and so on. Thus the ploughed surface shows a ridge, which should not stand up too high, every 22 yards; midway between the ridges are open furrows and these, though troublesome when drilling and with the binder at harvest, serve a useful purpose by acting as surface drains; it is for this reason that they are put nearer together on heavy land.

Setting out ridges causes a certain amount of waste time, though with an expert ploughman the loss is small. The only way of avoiding it is to work round and round the field, ploughing on all sides; this method is fairly common in some districts, but has not yet achieved any general popularity in this country. The roundabout system necessitates special measures to move the soil on the diagonals of the field, which is largely missed in turning at the four corners.

There are several points to be noted in good ploughing. As mentioned above, the centres of ridges should be moved, and this means that furrows should first be turned outwards when forming them; the ridges must not be too high. The furrow slices should be straight, otherwise some of the ground will be missed. An even depth of working should be maintained and all vegetable matter should be completely buried: to ensure the death and decay of the latter the furrow slices should be pressed well together. The ends of the work at the headlands should be neat so that no soil is left unmoved there; to make this easier, ploughmen often take the plough once along each end of the field to mark out the headland and so to give themselves a line for the ends of the furrow slices.

Other Forms of the Common Plough.—Nearly all modern ploughs are made of iron, but wooden ploughs are still in use in some districts. They are practically entirely restricted to heavy clay soils, where it is found that a wooden mould-board scours better (*i.e.*, runs cleaner) than an iron one; on these soils wheels are very apt to get clogged so that most wooden ploughs are swing ploughs, though some have one small wheel running under the fore end of the beam.

A large reduction of labour may be effected by the use of multiple furrow ploughs: as an instance, on light soils one man and three horses can work a double-furrow plough whilst it still takes one man and two horses to plough at half the rate with a single

plough. With expensive labour there is much to be said for multiple furrow ploughs, but on heavy soils they tend to block and single furrow ones do better work. A double-furrow plough would often require five or six horses on heavy land and except under dry conditions, these would all have to walk in the furrow, because of the puddling caused if they walked on the unploughed land. So many horses in single file would be awkward to manage and considerable difficulty would arise at the headlands, for one horse would hardly pull the plough out at the end of the furrow. With tractor ploughs two, three or four furrows are common.

Of rather a different type are one-way ploughs—curiously named implements since their distinguishing feature is that they can turn furrows in both directions instead of only one. With these, all furrows are laid in one direction—*e.g.*, to the north. They are of several forms, the most popular being the balance and the turn-over ploughs. The balance plough is really two separate implements with a single pair of wheels (Fig. 8). Whilst one plough is in action the other is carried in a vertical position in front of it; when the headland is reached the plough that has been engaged is lifted up and this brings the other one down into position for the return journey; as the horses walk round on the unploughed land the draught chain slips under the wheel on that side, so that no

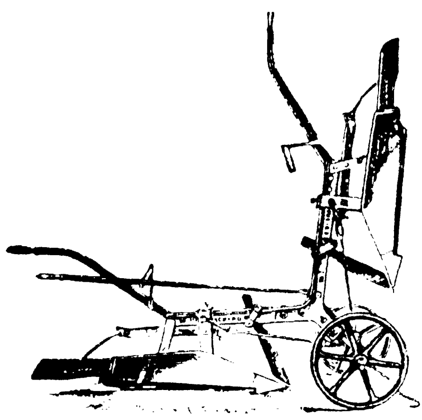


FIG. 8. BALANCE PLOUGH.

unhooking is necessary. Steam ploughs are, of course, multiple balance ploughs. In the turn-over plough there are two bodies fixed to one beam. When one is at work the other is carried horizontally and upside down above it; at the headland the implement is turned over on to a disc at the end of a projecting stalk, and as the horses get round the whole is pulled right over with the other body ready to engage. One way ploughs eliminate the trouble of setting out ridges, but though they enjoy a certain popularity in some districts they show little sign of spreading. It is clear that

they may be convenient in special cases, such as when it is required to plough close up behind folded sheep, and they are common for ploughing strips in market gardening and fruit growing.

SPECIAL PLOUGHS.—The ridging, or double mould-board, plough is used in growing potatoes and—except in southerly districts—roots. It has a short share with a narrow cutting edge perpendicular to the line of draught, no coulter, and a mould-board on each side of the body; it is only used after the land has been broken up with an ordinary plough and has been worked to a fairly fine condition. In its passage it excavates a triangular furrow, pushing and lifting the soil into narrow ridges on either side without inverting it; furrows are opened at 24 to 30 in. apart and then the two little ridges between each two furrows form one broad, well set-up ridge. With the object of keeping the ridges accurately at a constant distance apart, ridging ploughs are fitted with a marker, which scratches along the surface to give the line for the next furrow.

The potato digging plough is used to get the tubers out of the ridge when harvesting the crop. It has a share similar to the ridging plough and this runs under the tubers in the ridge; the double mould-board is replaced by bars which slant upwards and backwards from the share (in most cases mould-boards or bars can be fitted to the same body so that one implement can be made to serve two purposes). As the plough is drawn along the whole ridge is lifted up the slanting bars, but the soil tends to fall through them, leaving the tubers on the surface. In general, the implement is reasonably efficient, but it does not expose the tubers so well as the potato spinner, whose revolving arms throw them right clear; it is useful, however, as it will work when the potato tops have not died down sufficiently, or when the ridges are too massive for the spinner, also, as it leaves the tubers behind it, rather than throwing them to one side, it is useful for lifting the outside rows of a field. Further with small acreage or where the number of pickers is limited, it is useful to plough out every other row for it is not necessary for the pickers to keep pace with the plough in that case.

Special ploughs are also made for lifting sugar beet, as, except on the loosest soils, these roots can only be pulled by hand with great difficulty. There are a variety of ways of loosening beet, but the most common implement is a plough whose body is flat and very deep, with the front edge sharpened. The plough is drawn along one side of a row of beet and carries a share on the side of its lowest point which runs under the roots; this share slopes upwards and backwards so that as it passes under a root the latter is lifted. Provided the share is not too worn, when the plough runs round each root, the implement is extremely efficient, leaving the beet so that they can be pulled up very easily.

The general depth of working soils is about six inches, but at intervals and for special crops such as potatoes and sugar beet it is desirable to stir the lower depths so that plant roots can penetrate deeper. This is the object of the subsoil plough, whose

only working part is a single forward pointing tine. The subsoiler works directly behind an ordinary plough, being taken along the open furrow with its tine penetrating for a further four to six inches ; the disturbed subsoil is covered by the next furrow turned by the ordinary plough and thus the subsoil is broken up and aerated without any of it being brought to the surface. The same object may be achieved by fitting a subsoiling tine on to an ordinary plough, but owing to the greatly increased draught this is rarely done except when using steam power or a tractor.

Cultivators.—Cultivators are wheeled implements carrying a number of strong tines (usually seven or nine, arranged in two rows) that stir the soil to a depth of four to six inches. They may be used to break up the soil in place of a plough, but they are more commonly used to break up the furrow slice, the direction of working being at right angles to that of the ploughing. Their suitability for this rests largely on the strength of the tines and the depth to which they can penetrate. When working down a seed-bed the procedure is to start with a deep working implement and to follow with successively shallower ones, as then the seed-bed will be fine on top and firm below ; if, then, a cultivator is used in the process its place is next after the plough.

One action of the cultivator is to lighten the soil and open it up, and this is particularly desirable when, as the result of much rain, furrows have settled down in a "sad" condition ; the cultivator lightens the soil by breaking the furrow and allows water to drain through it and air to enter. The cultivator also has a considerable effect in bringing clods to the surface, where it is possible to deal with them, and in letting the finer soil down to form a good bottom to the seed-bed ; in addition to clods the cultivator brings weeds to the surface, where they can be collected and removed. Finally this deep stirring, if done when the conditions are good, has a very considerable pulverising action. There are many different types of cultivator and their relative efficiency in the above actions varies widely between the types.

Cultivators may be fitted with rigid or with spring tines. The latter are the more popular, but it might be urged in favour of rigid tines that they face their work better, and ensure that the soil is moved to the full depth to which the implement is set ; they are more suitable for deep work and will break up the soil below the plough furrow, whereas spring tines will only work as deep as the ploughing ; rigid tines are common on tractor cultivators. In the grubber type of cultivator the tines are straight or nearly so, but a greater pulverising effect is obtained when they are curved with the inside of the curve facing the work, the reason for this is that as the implement moves forward the soil piles up in front of each tine, and if the latter has a curve the column of soil is bent over on itself the principle employed in the digging plough. In some implements the curve is only for a short length near the point of the tine and the remainder is short and vertical, which helps in

clearing rubbish ; the more common form of curve, however, is the sharper one shown in Fig. 9, which leads to greater pulverisation.

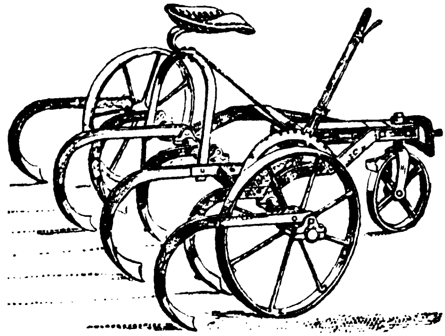


FIG. 9.—CULTIVATOR.

Special types of rigid tined cultivators are the three-drill grubber and the broadshare or stubble cleaner. The former is used for the deep stirring between the ridges soon after potatoes are planted, a single strong tine (or sometimes three tines) cutting deeply into each furrow. Each tine can be fitted with a double mould-board so that the implement can also be used as a ridger opening out three ridges at once ; this has the added advantage that if the same implement be used for both operations the ridges will be placed exactly right for the operations of the tines. The broadshare has a strong rectangular frame carrying three or more stout tines, each bearing a very broad share (about 18 in.) so that all the soil in the breadth is moved. The penetration is only about two inches but this is sufficient to give a bed in which the surface weed seeds will germinate, to be destroyed later in the subsequent ploughing; in addition to causing seeds to germinate the implement cuts all growing weeds and many are killed, especially if the operation be followed by dry weather. The broadshare is not a common implement, but it is a great help in keeping land clean : the draught is very heavy, a tractor being needed to pull it.

For most conditions spring tines are more efficient on a cultivator than rigid ones, because their vibration during work aids materially in pulverizing the soil. The vibration also helps in clearing the tines of weeds, and there is less danger of breakage if an obstacle be struck ; it is further claimed that the draught is reduced. The spring is obtained either by making the tines themselves flexible and resilient, or by having rigid tines working against circular springs in the frame, or by both methods.

With the exception of the stubble cleaner the points of cultivator tines are narrow or chisel shaped, though there is some variation between makes. In recent years models have been produced to the tines of which vertical knives may be fitted; the implement is then termed a grassland rejuvenator, its object being to make

cuts through turf to a depth of four or five inches, to open it up and aerate it.

Cultivators have two control levers. The position of one determines the depth of working and sometimes the angle of entry into the soil, whilst the other is for raising the tines clear of the ground. It is very important that the tines should be raised before the implement is turned or they will be bent. Cultivators for use with a tractor are fitted with a self-lift. The tractor driver pulls a bar forward by means of a piece of string, and this engages a toothed arc into corresponding teeth on one of the wheels; the tines are wound up out of the ground by the wheel's rotation, and on completion of the turn at the headland, another jerk on the string releases the arc and the tines drop back to their work. Similar self-lift devices are fitted to tractor ploughs.

Harrows.—Harrows differ from cultivators in having no wheels. They also have many more tines for the same width of working (the lateral distance apart of the tines being one and a half to three inches, as compared to six to nine inches), and consequently the pulverizing action is greater, although the tines are nearly, if not quite, straight. In general they may be regarded as surface working implements, though the depth of penetration varies extremely between the many different types in use. The action of the common forms is very different from the cultivator, for whilst the latter stirs up the soil, harrows have a consolidating effect—in fact, it has been said that the harrow is the best roller.

The common form of the implement is the zig-zag shown in Fig. 10, where the closeness of the working tracks is well illustrated.

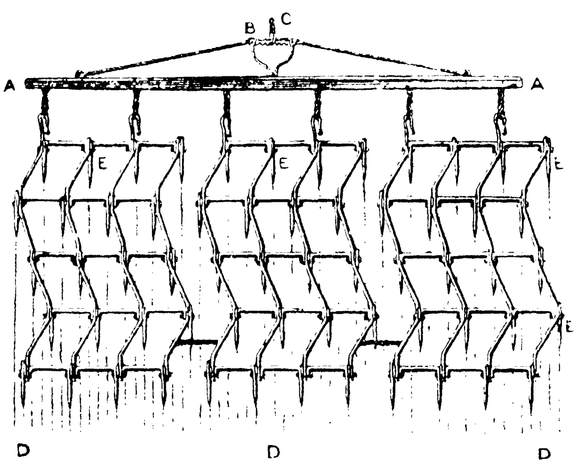


FIG. 10. ZIG-ZAG HARROW.

A A, draught beam.
B, hake.
C, draught chain.
A, B, C, A, whippletree.
D, D, D, tine marks.
E, E, E, teeth or tines.

Several advantages accrue from having separate small sections on one draught pole. The implement conforms more to the inequalities of the ground, turning at the headlands is easier, any section can be lifted easily by hand whilst in motion to allow it to clear itself of weeds and the sections can be packed on to each other when moving from field to field.

The rigid framed (*i.e* , each section is rigid) zig-zag type is made in all gradations of weight. The heaviest ones may need four horses, and will penetrate the soil to a considerable depth, indeed some are now available in which the front three rows of tines are chisel ended and point forwards, so that the whole is drawn very deeply into the ground, giving it much the same action as the cultivator, with the advantage of the greater number of tines. The common heavy type has duck-footed tines, *i.e.*, tines which are flattened and pointed forward at their tip and they tend to hold in to a depth of about three or four inches. These heavy ones are often called drag harrows and their function is to stir the soil to a depth of perhaps half that of the ploughing, to break clods and to bring weeds to the surface ; thus their place in the preparation of the seed-bed comes next after the cultivator, which in fact they often displace altogether. The term "drag-harrow" is commonly used to denote any type of harrow with curved tines.

Lighter harrows are made on the same pattern but have straight and shorter tines ; their function is to work the surface, breaking down the smaller clods, giving the mould necessary to cover the seed properly and to leave the field level. In general a farmer will possess three grades of zig-zag harrows—drag harrows, intermediate or two-horse harrows and a light single horse set ; the last are usually called seed harrows, as one of their main uses is to cover the seed after the drill It must not be supposed that a cultivator and all three grades of harrows are always used in preparing a seed-bed ; if the weather is favourable one or two operations after the plough may suffice, but where a number of implements are employed, the sequence is from the heavy, deep working ones to the light, shallow ones

All the above-mentioned harrows have one feature in common, namely a rigid frame for each section. This may be an advantage in some respects as the irregularities of the ground cause the sections to swing laterally and to go forward with a jerky motion, which helps to smash clods. It possesses a serious disadvantage, however, in that some of the tines may ride clear of the ground for considerable distances, as when a furrow is being straddled Of an altogether different type are chain harrows which have no rigidity and so fit closely to the ground however uneven the surface may be. There are a number of different forms of these flexible harrows but essentially they all consist of series of links. Their penetrative power is practically nil, but they are useful for rolling weeds together after they have been brought to the top and to make a fine tilth on the surface ; they are very commonly employed

on grassland to spread manure and molehills. Some chain harrows are provided with spikes, which vary in different makes from one to six inches in length. Such an implement, combining the penetrative power of the tined harrow with the flexibility of the chain harrow, is very useful in giving a tilth, and, if the spikes are long, is extremely efficient in tearing out a mat on old pasture.

The spring toothed harrow consists of a number of sickle-shaped tines mounted on a rigid frame, which is usually made in separate sections as with the zig-zag type. The angle at which the tines enter the ground may be varied and this determines the depth of working, which may be anything from a mere scratch on the surface to four or five inches. It has the advantage of being able to do much the same work as the cultivator or as various grades of harrows, which therefore it may displace on a small farm. This implement can also be obtained fitted with wheels and a self-lift mechanism for tractor work ; in this form it is really a low built cultivator and the great number and resilience of the tines makes it very efficient in giving a tilth.

The pitch-pole harrow is an implement of recent introduction, which has attained some popularity for tearing a thick mat on old pasture, and also for working arable land. It carries two sets of knife tines ; when the set in work blocks a jerk on a handle trips the other set into work, the former revolving backwards and clearing themselves of rubbish. The implement has a very drastic action and the heavy draught necessitates a tractor. The whole is built on one rigid frame so that it is not efficient on uneven ground.

Of an entirely different type is the disc harrow. This implement has a series of saucer shaped discs (of 12 to 16 in. diameter, and with sharp cutting edges) mounted about six inches apart on axles. The axles may be adjusted so that the discs run in the line of advance of the implement or at angles to it ; if set straight the discs cut to a depth of two to three inches, whilst if set at an angle they do not cut so deeply but exert a grinding and rasping action on clods. The disc harrow is an implement of heavy draught, but is very useful in forcing a tilth when dry weather conditions give very hard clods ; it is also useful for cutting a turf or a trodden surface before it is ploughed over, so that the bottom of the furrow may not lie hollow. With tractors a double set is often used, the front and rear row axles being angled in opposite directions ; in some cases one row of discs is notched, this form being believed to give more mould.

Rolls.—The functions of rolls are to consolidate the ground, to crush clods and break surface pans and to level the top. Rolls are usually 18 to 24 in. in diameter ; for a given weight the smaller the diameter the less is the area of the surface in contact with the soil and consequently consolidation is greater and the draught heavier. Consolidation is necessary to give plants a good roothold and to press the soil particles close to the roots. This is often particularly needful in spring for autumn sown plants which may have been lifted almost out of the ground by frosts. It is often claimed that

rolling brings moisture up from the subsoil by increasing capillarity, and though this has been very generally accepted in the past doubts have been thrown on it in recent years; an alternative possibility is that consolidation, by pressing the soil more closely to the roots of plants, increases the efficiency of the latter in taking up moisture. The crushing effect on clods is very dependent on their moisture condition; rolls must never be used when the soil is wet, but clods will not break down readily when they are dry and baked; after one or two alternations of wetting and drying, however, they will crumble down easily under the roll. A surface pan, being a thin layer, will crumble readily when dry, particularly if the roll has a ribbed surface. Finally the levelling action of the roll is of great importance, for this it is often the last implement used before sowing small seeds, whose low food reserves necessitate shallow sowing, which is only possible when the surface is smooth. Surface evenness is also highly desirable for the working of the binder or of the mower and to provide this the roll is often used in spring.

Every farmer must have a roll available, but the implement is more in evidence on light than on heavy soils, for on loose land consolidation is obviously more important. On heavier soils the function of the roll is more that of a clod crusher, and the greatest care has to be exercised in using it because of the danger of making clays run together, or "puddle," a condition that can only be remedied by weather and time. On heavy soils the roll is rarely used in autumn, because of the danger of winter capping, and in spring it must be rigidly withheld until the land is dry enough; as an old saying has it, "a March roll makes an April fool."

Rolls are made with a flat or a ribbed surface. Flat rolls can be obtained of a variety of weights but about one-half ton is the most common, this being within the capacity of one horse. Some are made of stone or even wood but iron or steel is the more usual material. It is important that the cylinder should not be all in one section, as if so there is considerable disturbance of the surface in turning; commonly there are two or three sections and the total width is about seven feet.

A ribbed surface is the characteristic of the ring or Cambridge roll. In this there are a number of narrow sections—each two to three inches wide—running freely on a central axis with a certain amount of play between them so that they may clear themselves of soil. Each section is raised in its centre to a narrow rim, so that the implement leaves a characteristic pattern on the surface of the field—a series of narrow grooves with very small ridges between them, the depth of the grooves below the tops of the little intervening ridges being about one inch. Ring rolls are usually made heavier than flat rolls and a seven feet width requires two, or sometimes three, horses. The consolidating effect is therefore considerable, nevertheless, the lateral pressure of the rims leaves the spaces between the grooves quite loose and the surface of the soil is much less liable

to cap after the ring than after the flat roll. The weight being concentrated on narrow rims the ring roll is very effective as a clod crusher and will often smash them down when a flat roll will not break them at all. Special advantage may be taken of the tracks left by a ring roll in the sowing of grass and clover seeds, which need covering with a very shallow layer of soil. If the seeds be broadcast on to a ring-rolled surface a large proportion will fall into the grooves, and then if a flat roll be taken over the field soil from the tops of the little ridges will be pressed into the grooves, giving a good cover to the seeds.

The clod crushing effect of the roll is sometimes obtained by a very different implement, termed the planker or rubber. This consists of a set of five or six thick, heavy planks fastened together and lying not quite horizontally, so that one corner of each rests on the ground. When pulled along, these corners, which are shod with iron, have a considerable effect in scraping pieces from clods. The draught is fairly heavy, two good horses being required, but it is a very useful implement where the surface is dry and the soil below is still too wet to allow the use of the roll; in addition, if the clods be small and very dry the planker may be more effective in breaking them than the ring roll.

Drills.—The simplest and cheapest method of sowing seed is to broadcast it on the surface and to give it a light covering of soil by harrowing. This method has, however, the disadvantage of uneven depth of covering and much seed is left on the surface at the mercy of the birds; furthermore it is often necessary to sow the seed rather more deeply in order to place it among moist soil. It was during the eighteenth century that drilling supplanted broad casting, thanks largely to the pioneer work of Jethro Tull.

In addition to even depth of covering drilling may claim some advantage as leaving the seed in rows so that subsequent hoeing becomes possible. On the other hand, restricting the seed to rows means that much of the soil surface is bare, and since, in cereals, over-crowding as well as sparseness of plant have both been shown to reduce yield, where hoeing is not intended this may be a disadvantage. It is definitely clear that if the seed is drilled in rows it is of great importance that the drill should deliver it regularly.

Where broadcasting is still carried out it is usually done by hand, or by taking a drill over the field with the coulters raised clear of the ground. With the seeds of grasses and clovers, however, a hand seed barrow is quite commonly used. This consists of a long (eight to nine feet) box carried transversely on an ordinary barrow frame; the box carries the seed and has a series of openings in its rear side out of which small streams of seeds are passed by brushes revolved by gearing to the front wheel. In some districts "fiddles" are used for broadcasting the seed of a variety of crops; the fiddle is carried by a man and consists of a container from which the seed pours slowly on to a horizontal disc—which is rotated to the right

and to the left by means of a toothed rod working in notches, the action being similar to that of a violinist with his bow.

With drills two types of delivery are common—the cup and the force feed. In the cup feed type of drill there are two corn boxes, a top one carrying the bulk of the seed and a lower one divided into chambers into which the seed flows, Fig. 11. Through the latter runs a spindle bearing in each chamber a large vertical disc, from the

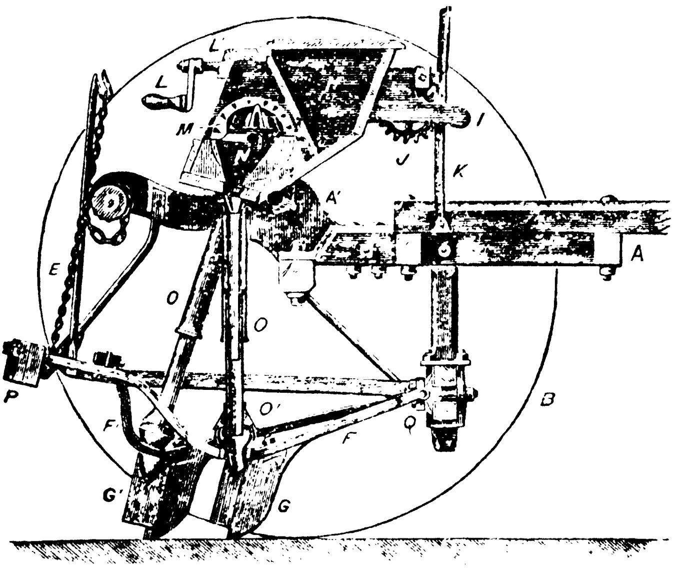


FIG. 11. CUP DRILL, VERTICAL SECTION, SHOWING PARTS.

A, frame.
A', iron side for supporting corn box
B, outline of travelling wheel.
C, axle.
D, hind barrel or roller, for winding lever-chains.
E, lever-chain.
F, F', fore and hind levers
G, G', fore and hind coulters
H, corn box.
I, box-regulator.
J, worm wheel.
K, vertical rack.
L, regulator crank.
L', spindle with worm gearing into
N, hopper, or funnel.
O, O, conductors, or spouts.
O', spherical cup connecting conductor with coulter.
P, lever weight.
Q, lever joint.
R, steerage tongs.

periphery of which a series of cups protrude; the spindle is driven from one of the travelling wheels and as it rotates the cups pick up little loads of seed and empty them into the funnels leading to the coulters. The seed rate is varied by changing the cog wheels connecting the spindle and the travelling wheel and thus varying the rate of rotation of the spindle; in addition, a separate spindle with smaller cups is supplied for use with small seeds. Another method of regulation, introduced in a newer type, is by fixing the cups so that the amount of their surface protruding may be varied

at will by means of a screw. The details of the force feed type of delivery vary considerably, but in general, there is some form of toothed wheel running in the bottom of the seed-box, forcing seed out between its teeth. This method allows of rapid adjustment of the seed rate by altering the area of the teeth which deliver into the coulter funnels and has an advantage over the cup feed on hilly or rough ground, where cup loads are liable to great variation: on the other hand some of the seed is broken in the force feed and trials have shown that there is little to choose between the two types as regards regularity of delivery.

The seed passes from the delivery mechanism by a flexible tube to the ground through coulters which cut tracks for it. In some drills the tracks are cut by discs against the lower edges of which the seed tubes open. Disc coulters are very useful for cutting seed in across plough furrows, but they provide a serious temptation to drill seed when the soil is not really in a fit state; they are commonly employed under more extensive conditions of farming. The depth of drilling is determined by the pressure put on the coulters; the pressure is obtained either by weights, by springs, or by means of a bar, running transversely across them, which can be forced down. Cup feed drills are usually fitted with weights and a pressure bar.

Considerable care has to be taken in drilling to avoid gaps or over-lapping between adjacent drill breadths; one travelling wheel has to be kept running in the track it made during the previous passage. A skilful man can do good work without any aid, but for the best results some form of steerage is necessary. The commonest type is a forecarriage which is held to the line by an extra man; alternatively there is a type of steerage which is controlled from behind the drill by the man walking at the rear and watching the coulters to see that none of them gets blocked.

Methods of delivery and types of coulters and steerage can be combined in one implement in various ways. The Suffolk drill has a cup feed, plain coulters and front steerage and is a weighty implement suitable for heavy soils. The Bedford drill differs in being lighter and having a steerage controlled from behind. The American type has a force feed, disc coulters and no steerage. A turnip drill for sowing on the tops of ridges has a different sort of steerage in the form of dished rollers, which fit over the ridges and run in front of the coulters holding them in place. These are the common drills in use in this country; a number of other principles have been introduced into modern drills, but in general these are still in the experimental stage.

A special drill is made for ploughing in beans and is quite commonly used: the implement is small and fixes on to a plough between the stilts of which it runs. It consists of a single hopper with a wheel running on the bottom of the newly opened furrow just behind the mould-board; the wheel operates a cup feed mechanism and there is, of course, no coulter, the seed merely

dropping into the furrow bottom and being covered by the next furrow slice. The usual practice is to sow beans in every second furrow, though where the land is foul and considerable intercultivation is desired, they may be put in every third furrow.

Combine drills are becoming fairly common, their object being to sow artificial manure and seed at the same time. They carry a box for the manure in front of the seed box, and the manure is fed to the ground either through the same coulters as the seed or through a different set. Besides saving labour these drills have the advantage of depositing the manure close (actually just underneath) the seed, thus economizing it. Undoubtedly other labour-saving combinations are possible, but few are in general use in this country Drills are usually provided with rings to drag along behind the coulters and these may cover the seed satisfactorily and so obviate harrowing where the soil is in a fine state, but they are rarely used.

Drills in common use vary in width between six feet six inches and eight feet six inches, but much wider ones, suitable for tractor work, are gaining in popularity. They are supplied with sufficient coulters to give rows six inches apart; some old drills for sowing grass seeds can sow rows as close as three inches. Where wide rows are required, as with root crops, the necessary number of coulters can be removed, the remaining ones correctly spaced and the unwanted delivery funnels closed up.

Horsehoes.—The primary object of hoeing is to kill weeds. It is carried out in the early stages of the growth of the crop—often as soon as the rows are visible—with the idea of freeing the latter from competition until established. When the crop gets big its smothering action will keep weeds in check and hoeing becomes impossible because of the danger of damaging the crop plants, particularly their roots. Weed destruction is not, however, the only benefit from hoeing. As the weeds are cut just below the surface of the ground the operation serves to loosen the top inch or so and thus aerate the soil: plant roots and soil organisms need oxygen and produce carbon dioxide and consequently healthy growth demands considerable diffusion of the former into, and of the latter out of the soil, so that looseness at the surface is very desirable. It has been widely held that this surface mulch is also of considerable value as a means of conserving moisture, by breaking capillarity so that water is not brought from the subsoil right to the surface where it will be evaporated: recent work, however, suggests that the effect is small and is only operative where there is a water table within from four to six feet of the surface. Nevertheless hoeing does save considerable quantities of water for the use of the crop by eradicating weeds and thus preventing valuable supplies being dissipated by their transpiration.

The most efficient method of hoeing is by hand, because in that it is possible to work much closer to the crop rows, or even in them. But horse-hoeing is much quicker and consequently

cheaper, so that the whole trend now is towards more horse and less hand-hoeing.

There are very many different horsehoes on the market; a simple classification of them is into single and multiple row types. Single row horsehoes, though of course much less rapid in action, have one advantage in that they may be set to run very close up to the crop rows, for which purpose they are made in an expanding form. Such a hoe usually carries five tines arranged in three lines in the shape of a wedge, thus though only a small width is covered that width is worked very thoroughly and there is also plenty of room between the lines of tines for the surface weeds to clear themselves. One man and one horse only are required. The depth of working may be regulated by raising or lowering the fore wheel, and the implement is most commonly used between the rows of potatoes and beans (Fig. 12).

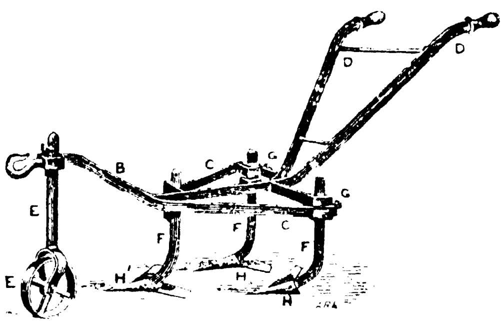


FIG. 12. SINGLE ROW ROOT HORSE HOE, OR GRUBBER.

A, draught hook.
B, beam.
C C, frame.
E E, wheel and standard.
F F F, knife standards.
G G, clamps for two side front [illegible]

For multiple row horsehoes some form of steerage is required; this usually consists of a fore-carriage with wheels on which the body of the implement can be swung laterally for a few inches by the operating handles behind. The tines are carried on one or more commonly two transverse bars. The number of rows taken naturally depends on the distance between them and on the width of the implement, but with root crops it is generally three or four. The common practice is to cover half of each of the outside rows, so that when taking four, the ground moved [illegible]st of three complete inter-row spaces and half of each [illegible] two spaces flanking them. Generally three tines work in e[illegible] space, one being carried on the front bar and taking the midd[illegible] the space, whilst the other two are carried on the rear bar and [illegible] the sides. In some cases only one tine works in each inter-ro[illegible]ce; this is usual either when it is required to stir the soil de[illegible], in which case three tines per row would make the draught [illegible] heavy, or when the plants are only just through and it is impossible to see

the rows plainly enough to work close up to them. Care is necessary with the multiple row hoe to avoid cutting up the crop plants and the man holding the handles is fully employed, so that he is usually given a boy to lead the one horse required to pull the implement.

There are two fairly distinct types of body fitted to multiple row horsehoes. For working between the rows of young root crops a low built one gives greater control, but when the tops of the plants get bigger the bars of this type of body will not clear them and a higher built frame has to be employed.

There are many peculiarities among the implements in common use and two are particularly to be recommended. One is built on the principle of having each unit of three tines sprung separately, so that an inequality of the ground does not affect the whole implement. In the other, discs are fitted to run on both sides of each row of crop plants, so preventing any soil from being thrown on them—a matter of some importance when the plants are small.

The form of the blades on the points of the tines has considerable effect on the work done. For deep work chisel points, very like those of a cultivator, are best, whilst for medium work A-shaped blades are used. As the crop grows its roots spread laterally and deep stirring becomes undesirable and then L-shaped blades are commonly employed, particularly on the tines running next to the crop rows. Though useless against perennials these blades deal effectively with young seedlings, but they require a fine surface tilth to work properly.

Horsehoes are occasionally used on cereals (which have to be drilled in rows at least eight inches apart for the purpose), but their more common use is on pulse and root crops, the latter of which should be horsehoed at least twice and preferably more times, in addition to one or more handhoeings. With root crops much hand labour has to be expended in thinning out the plants in the row and various implements have been designed to do this operation, but they have not proved very satisfactory. Plants may, in fact, be bunched by taking an ordinary horsehoe transversely across the drill rows, but hand singling is far more common as it is the only method in which the best can be made of a gappy "plant."

Manure Distributors.—Farmyard manure is usually spread by hand despite the fact that efficient distributors are available. The wide adoption of mechanical spreading is prevented by the initial outlay involved, since at least three spreaders would be required for the organization of a working set. With small-holders and in other special cases, however, there would appear to be an opening for them. The implement is in the form of a low-sided waggon in the bottom of which there is a travelling band taking the manure to the rear, where it is broken up and thrown out by beaters. Two horses are required; the load is about 15 cwt. and it is spread over a width of four to five feet; the spreading is very perfect and considerably better than can be achieved by hand.

With artificial manures the position is the reverse, in that,

though they can be and sometimes are, sown by hand, they are generally sown with a manure drill. This is because they are concentrated, with the consequences that only small amounts are applied per acre and that even distribution is very important; in addition, artificial manures are often very dusty and a man broadcasting by hand is subject to considerable discomfort, much of which is avoided by the use of a drill.

Even distribution is the primary necessity with a manure drill, and this has become yet more important with the recent introduction of new, highly concentrated compound fertilizers; fortunately these latter are crystalline, a condition facilitating even distribution. The fertilizer should be delivered near ground level, or it should be protected from the wind during its fall, otherwise bad work will be done during stormy weather. Some artificial manures, particularly superphosphate, are sticky in nature and in the construction of a good drill special precautions are taken to prevent them from forming into lumps and from "bridging" across the container as the latter empties. In addition, a manure drill should be easy to clean out and should sow the correct amount at each setting. The latter ideal is rarely attained, and in all cases the rate of sowing should be checked after a small proportion of the work has been done. There are many different types of manure drill on the

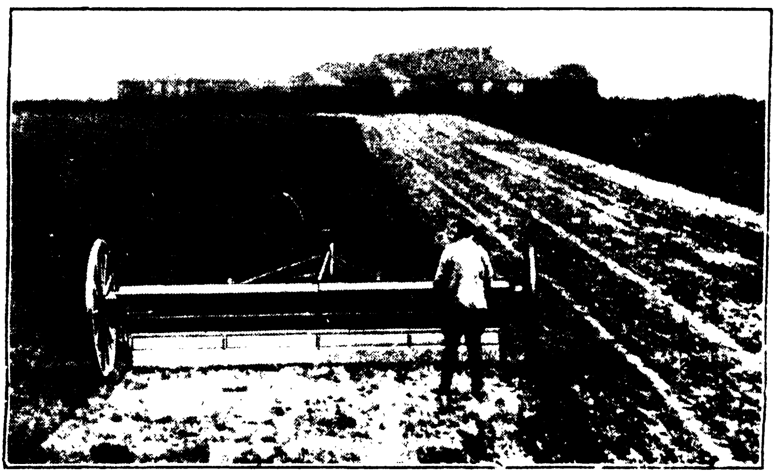


FIG. 13. MANURE DISTRIBUTOR

market, and though most of them do fairly good work there is still much room for improvement, particularly as regards evenness of distribution (Fig. 13).

In one type of distributor which has enjoyed some popularity in the past, the fertilizer is contained in a round hopper from which a stream drops on to horizontally rotating discs, which broadcast

by centrifugal force; some form of agitator is necessary in the hopper. This type gives a poor distribution, especially on windy days, and the commoner forms in use at present, have a long narrow hopper which extends across the whole width of working and which delivers all along its length. With this type of container delivery may be either from the top or from the bottom. If the latter, the actual mechanism may be a worm shaft, an endless chain, toothed horizontal discs, or a spiked spindle sweeping small quantities through holes in the floor of the hopper; alternatively the bottom of the hopper may be occupied by rollers, either fluted, when the delivery is similar to that of a force feed seed drill, or smooth, when each roller carries a film of fertilizer which is brushed off by a scraper and falls to the ground.

In all these cases there must be an agitator working inside the hopper; this prevents bridging (*i.e.*, the condition when the material does not fall down to the delivery mechanism and a hollow is formed above the latter), but at the same time it tends to get some fertilizers into a lumpy state. The advantage of delivery from the top of the hopper is that there is no part moving within the fertilizer mass (and thus no tendency to lumpiness) and no danger of bridging. The principle is that the floor of the hopper rises very slowly as the drill works, pushing the fertilizer steadily upwards; at the surface of the fertilizer a spindle revolves, and this bears spikes which sweep small quantities backwards over the edge. It must be accounted a disadvantage of this type that the manure has further to fall to the ground.

Most drills will distribute any required amount from one cwt. to ten cwt. per acre of any common artificial manure; they are eight to ten feet in width, and one horse is sufficient to pull them, except on soft or very rough ground. If the bags of manure are placed conveniently along the headland, 10 to 15 acres should be covered in a day.

The combined seed and manure drill, which economizes fertilizers by placing them immediately below the rows of crop plants, has already been mentioned (page 53).

Labour Required and Acreage Covered.—The draught of an implement varies between wide limits according to the nature and condition of the soil, and to the depth and the width of working, so that the same implement may require two, three or four horses to pull it at different times and on different soils. Similarly the acreage covered is very variable; it can readily be calculated that if a team walks at two miles per hour then a plough turning a 9-inch furrow will cover an acre in five and half hours, but in actual practice much longer would be taken, because of the time wasted in turning at the headlands and of the many little rests that are taken; for this reason considerably larger areas are covered in a day when working on large square fields than when on small irregularly shaped ones. It follows that no very precise figures as to horses required and acreage covered can be given, and those in

Table I., must only be taken as general guides for the conditions stated.

The heavier implements are often drawn by a tractor working longer hours and moving more quickly than horses. Recent work has shown that speed is desirable *per se*, as the draught of a tillage implement does not increase in direct proportion to its rate of progress; thus the force required to pull an implement at four miles per hour is less than double that required, under the same working conditions, to pull it at two miles per hour. Tractor implements are usually of greater width than the corresponding horse implements, in which case the area worked may be three, four or more times as great as the figure given; for ease of comparison horse traction only is considered in the Table. Three or four horses can be hitched abreast and managed by one man, but it is still common to have larger teams than two in two lines, the front ones being controlled by a boy. The time spent actually working by a team of horses rarely exceeds seven hours in a day.

TABLE I.

		Team Required		Acres per Day.
		(Boys	Horses)	
				½
	Light			1
Digging plough	Medium			1¼
Double furrow plough				1¾
" "	Light			2
Ridging plough ...				2½
Beet lifter				2
Cultivator ...				
Drag harrow				6
Disc harrow ...				8
Medium harrow				
Light harrow				
Chain harrow ...				
Spiked chain harrow				
Ring Roll				
F[illegible]				
Suffolk drill ...				
Bedford drill				10
American drill ...				12
Single row horse hoe				2
Multiple row horse hoe				7

Haymaking Implements.—The grass mower which, wherever possible is invariably used for cutting hay crops, is illustrated in Fig. 14. The essential part of the machine is the cutter bar which lies very close to the ground, and being flexibly attached to the body of the machine, conforms to irregularities of the surface. It carries a series of fingers through which the knife travels, the latter having a rapid reciprocating movement imparted to it by a connecting rod from a crank wheel which is geared to one of the travelling wheels of the machine. The knife consists of a narrow bar to which are rivetted V-shaped sections, each of three inches breadth at the base;

the motion of the knife through the fingers gives a cutting action similar to that of scissors, the edges involved being those of the sides of the sections and those of hard ledger plates fitted to the lower faces of the slots in the fingers.

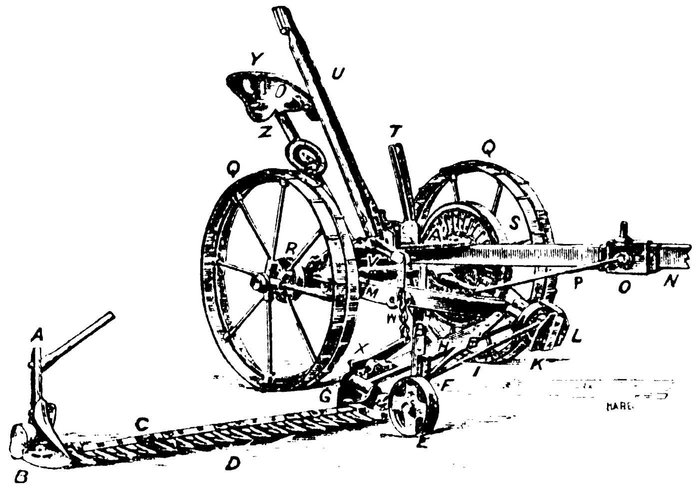


FIG. 14. MOWING MACHINE.

A, track board.
B, offside (or divider) shoe.
C, finger beam.
D, fingers.
E, main shoe wheel.
F, axle plate to ditto.
G, bracket to main shoe.
H, swing beam.
I, connecting rod.
K, crank wheel.
L, crank guard.
M, main frame.
N, whippletree bracket.
O, slide to ditto.
P, draught rod.
Q Q, travelling wheels.
R, ratchet pinion.
S, guard to spur wheel.
T, tipping lever.
U, lifting lever.
V, lifting quadrant.
W, lifting chain.
X, extension piece.
Y, seat.
Z, seat spring.
A', pole bracket.
B B', stays to swing beam.

Several conditions are necessary for perfect work. Firstly, the knife must run true in its path: a common fault in this connection arises through the bending back of the track board end of the cutter bar, and another through the vertical sagging of the bar in the middle of its length; either of these leads to strain being put on the knife, increasing the draught considerably and giving a tearing, rather than a cutting, action on the grass. Secondly, the ledger plates of the fingers must not be worn, for in that case their edges will be dull and rounded, and again the herbage will be torn rather than cut; they should be ground down or replaced as necessary. Thirdly, the knife caps must be correctly adjusted; these are fitted to the cutter bar and project over the back of the knife, holding it down to its work; whilst they must not press heavily on the knife

sections, the clearance should not be more than the thickness of a sheet of paper, otherwise the cutting edges of the knife and of the fingers will not be in contact. Finally, the edges of the knife sections must be sharp and this usually necessitates filing after about two hours work. A machine is supplied with two knives so that one may be sharpened whilst the other is in use.

Lifters may be obtained for fitting to the cutter bar when working with crops, such as peas and vetches, which lie almost flat on the ground. Their shape is that of a large finger, and they protrude about two feet forward, their upper bars sloping upwards and backwards; the stems of the crop plants ride up this slope, clear of the knife. Other features sometimes incorporated in the grass mower are two-speed gearing (the lower speed of knife being used with clovers and easy work), and an oil bath enclosing the crank shaft and gearing; in the absence of the latter frequent oiling is essential. Whilst standing still the machine should always be put out of gear by means of the clutch provided for that purpose: for travelling from field to field the cutter bar is raised and fixed in a vertical position.

A machine cutting a width of four feet six inches is well within the capacity of two horses, which can be expected to work for about six hours; in some districts it is the common practice to have three horses in the field when a full day's work can be done, each horse being rested in turn. Under good conditions rather over an acre is covered in an hour, but the speed of working is greatly reduced when the crop does not stand up well. The machine may also be used with a tractor, but to employ the latter to the best advantage a special implement is desirable; this consists merely of a cutter bar, the knife being driven direct by a power take-off from the tractor. Such cutter bars take a greater width than those of horse-drawn machines; in this case there is sufficient power for taking much greater widths, but expansion is limited by the tendency of the bar to sag in the middle and by the necessity of conforming closely to the surface of the ground.

The general method of making hay is to leave it in the original swathe for about two days after cutting and then, if the weather be fine, to turn the swathes over so that their under sides may be exposed to the wind and the sun; in unsettled weather this may have to be repeated several times, until the swathes are considered sufficiently dried to be collected, when four are put together into one windrow to facilitate loading. For this purpose a variety of "Swathe Turners" is available, and most of them are efficient in that they turn the hay over gently, so that the leaf (especially of clovers) does not fall off, and also in leaving swathes which are loose and light, a condition necessary for rapid drying. Good work is performed by machines which have sets of whirling tines or discs carrying small, free swinging forks, but the type illustrated in Fig. 15 is particularly to be recommended, because of its versatility. That implement is often termed a "Side Delivery Rake," since, when

working with all its prongs in position, two swathes are rolled together to one side; by travelling in the opposite direction two more may be brought up from the other side, giving a windrow of four swathes. If, however, the centre sections of the rakes be removed each swathe will be turned separately.

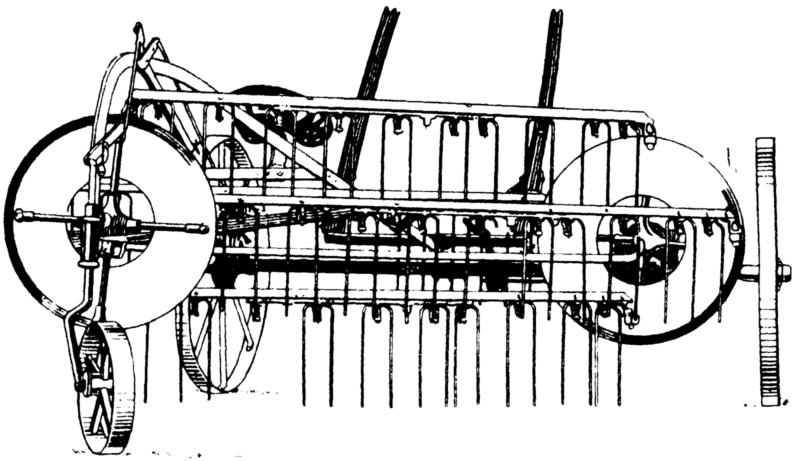


FIG. 15.—SIDE DELIVERY RAKE

A third possibility exists with this machine, for its action may be reversed and quickened, in which case the swathes are broken up and the material spread out. This so-called "tedding" is to be avoided if possible, because a considerable proportion of leaf is lost when it is done and especially in the subsequent collection, and it is rarely necessary in the drier districts of the country; however, although the best hay is made by keeping it in the swathe until ready for the windrow, if very wet weather is experienced it will get soaked right through and the only means of drying it may be to spread it out. A special machine the "Tedder" is available for this purpose, but its action is drastic, and it is not so popular as it was formerly.

Where the material has been tedded it must, after drying, be collected together again by a "Horse Rake" (Fig. 16). This implements gathers up all loose material on the surface of the ground and when full is emptied by pulling the operating handle, which raises the teeth; it is light in draught and is now made in ever increasing widths to economize labour, some folding device, or means of shutting it up like a concertina, being incorporated to enable it to pass through gateways. It may also be used to. collected swathes when very heavy rain has beaten them into the ground so that the side delivery

rake passes over them, but its main function is to clean up a field of any loose material after the crop (either of hay or of corn) has been carted.

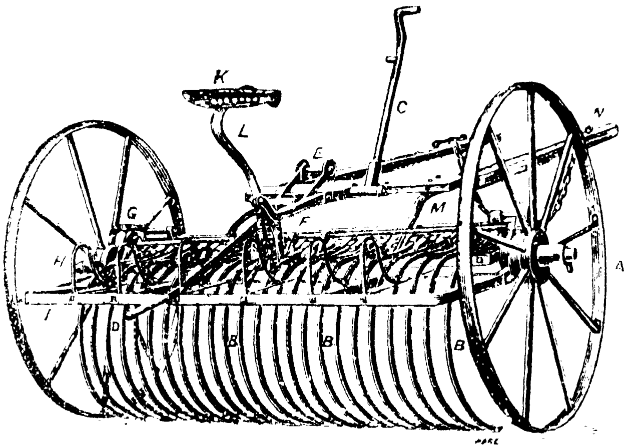


FIG. 16 SELF ACTING HORSE RAKE.

A, road wheel.
B, teeth.
C, front hand lever.
D, back hand lever.
F, treadle for automatic delivery.
G, spring for lever.
H, clearing rods.
I, back frame.
K, seat.
L, seat standard.
M, shaft iron.
N, shaft.

Until recent years hay was pitched by hand from windrows or cocks on to carts or waggons, and from thence to the stack, but with the increase in the price of labour several implements have

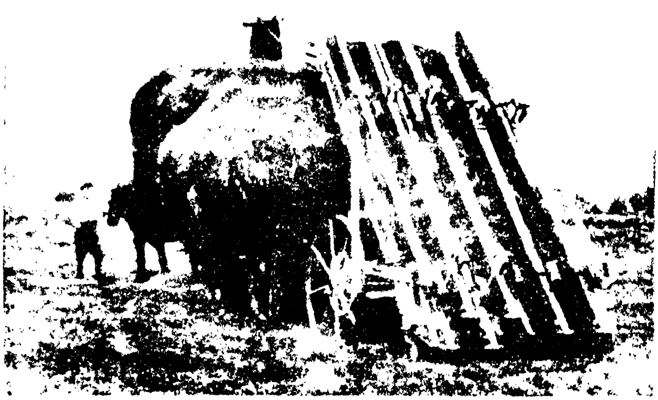


FIG. 17. HAY LOADER.

been evolved to do this work more expeditiously and they have spread rapidly into practice. The "Hay Loader" picks up material from the windrow and is hitched to the back of a vehicle on to which it delivers; in one type the principle is similar to that of the elevator (Fig. 17), whilst in another the hay is raised by reciprocating bar rakes. Work is facilitated by fitting skeleton sides to the vehicles to be loaded. Dealing with the material on the load as it is delivered there is heavy work, as it becomes matted together in a continuous stream, and two men are fully employed. A chain horse is usually attached whilst loading, as the implement increases the draught of the vehicle considerably: the loader is actuated by gearing from its own travelling wheels and can rapidly be transferred from one cart or waggon to another (Fig. 17).

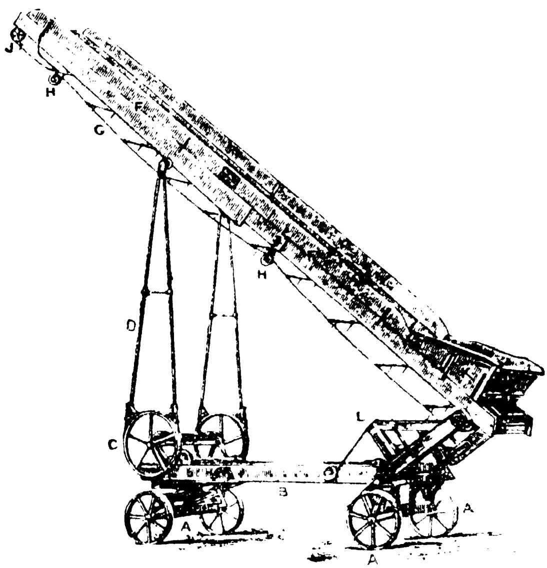


FIG. 18. STACKING MACHINE OR ELEVATOR.

A, travelling wheels.
B, frame.
C, cogged wheels for raising the lifting rods, D.
E, worm screw for working lifting rods, D.
F, trough up which the material travels.
G, endless chain, with forks for carrying the material up the trough (seen returning beneath the trough).
H, guide pulley for endless chain.
J, adjustments for regulating endless chain.
K, hopper for receiving material to be stacked.
L, lifting gear for raising hopper. The hopper is shown *half-raised*. By raising the hopper, as required, the top end of the trough is kept continuously above the middle of the stack. Consequently, from beginning to end, the delivery takes place over the *middle* of the stack.
M, horse gear for working endless chain of elevator.
N, connecting rod of ditto.

The movement of the hay from the load to the stack has also now been largely mechanised, the implement most commonly used being the "Elevator" (Fig. 18). By means of lifting rods the delivery end of the elevator may be raised or lowered; thus at the bottom of the stack its platform will be nearly horizontal, the angle being increased as the stack rises. An endless, fork-bearing, chain travels along the platform carrying the material up from the hopper, into which vehicles are unloaded; the hay has thus to be moved downwards by hand rather than upwards, and in some elevators the hopper is especially low, some machines even picking material up from the ground. Motive power is supplied by a small petrol engine or by horse gearing, the horse walking round and round in a circle; the same implement is also used for straw when threshing, in which case it is driven by a belt from a pulley on the threshing machine.

Another method of transferring hay to the stack is provided by the "Horse Fork." This consists of a grab, suspended on ropes from a crane or from the beam of a barn, the ropes being attached to a horse at their other end; the grab is lowered on to a cart or to a heap on the ground, the fangs enclosing a large bulk of hay, and is then raised by leading the horse away. Having been swung over the stack the grab is released by a pull on a cord.

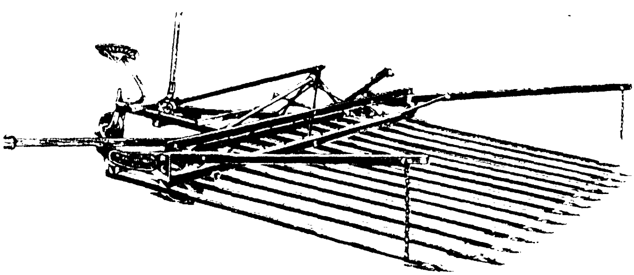


FIG. 19. HAY SWEEP.

"Hay Sweeps" have been introduced during recent years and are rapidly gaining a larger footing in practice because of the saving of labour associated with their use. A common form has 12 teeth protruding 10 ft. to the front in a width of 12 to 15 ft.; it is pulled by two horses, one walking on each side, and is provided with a seat at the rear for the driver and usually has a lifting mechanism for the teeth, to diminish the danger of their penetrating the ground where the latter is uneven. Sweeps may also be attached to the front of tractors. Hay may be picked up from windrows, from cocks or from the swathe, and half a cart load may be collected at once. As may be imagined the work is extremely rapid, enabling the farmer to take full advantage of fleeting spells of fine weather; this is an important consideration, but against it must be set the fact that sweeps can only be used where the stack is made in the

same field and that they are unsuitable for use on very uneven ground, as in a field with high-backed ridges. (Figs. 19 and 20).

The height of rapidity and the minimum of labour expense are reached where sweeps are used in conjunction with a "Stacker." This implement consists essentially of a long arm to the end of which teeth, similar to those of a sweep, are attached. The arm is laid along the ground with the teeth pointing away from the

FIG. 20. HAY SWEEP IN ACTION

stack and a sweep is driven up to it and then backed away, leaving its load on the teeth of the stacker. The arm is then raised by a small petrol engine and as it passes the vertical and travels backwards over the stack the hay falls down on it.

HARVESTING IMPLEMENTS.

Although the grass mower is occasionally used for cutting corn (when the crop is very badly laid), it is not very suitable for that purpose, because it gives a continuous swathe and does not clear the way for the horses for the next round. These disadvantages are overcome by the "Sail Reaper" (Fig. 21). In this machine the cutting mechanism is similar to that of the grass mower, consisting of a reciprocating knife working through fingers, but the cut corn falls back on to a platform. The chief feature of the machine is a series of four or six revolving rakes which sweep the corn to the knife and then clear the platform, depositing the cut material in sheaves to one side. Two horses are sufficient to pull the machine and it is preferred to the more complicated binder for laid corn because the latter cannot deal effectively with twisted material; it is the usual implement employed to cut seed clover, where great care is necessary to minimize shattering.

Machines for cutting corn were improved step by step until in 1875 a large advance was made by the production of the "Binder"

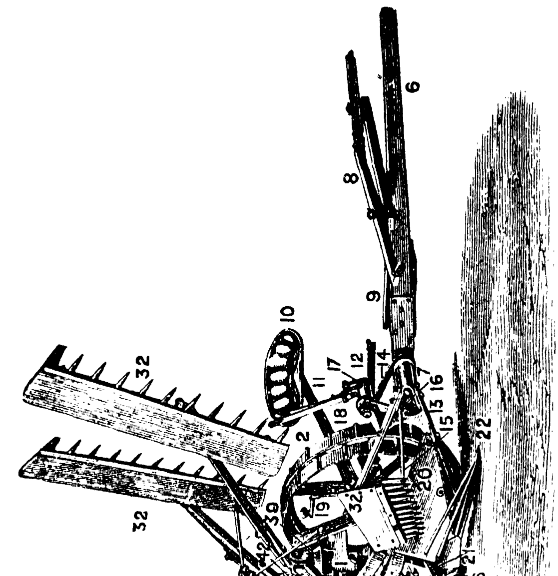


FIG. 21 SELF-DELIVERY REAPER.

1, main bracket. 2, main road wheel. 3, swivel wheel. 4, scraper for swivel wheel. 5, swivel wheel joint. 6, pole. 7, pole joint. 8, whippletrees. 9, tool box. 10, seat. 11, seat support. 12, foot bar. 13, frame irons. 14, sole stay. 15, stay for platform. 16, slotted bracket and quadrant. 17, tilting bracket. 18, tilting lever. 19, raising handle. 20, shield for gearing. 21, connecting rod. 22, corn lifter. 23, cutter bar, or finger beam. 24, fingers. 25, knife. 26, knife clip. 27, divider. 28, divider board. 29, top horn. 30, panel. 31, platform. 32, rakes, or sails. 33, rake arms. 34, rake teeth. 35, rake adjusting bracket. 36, rake stay for adjustment. 37, rake hanger bracket. 38, rake socket. 39, rake centre and crown wheel. 40, hanger rods. 41, hanger rod brackets. 42, dummy hanger bracket.

(Fig. 22), which, with minor modifications, has continued to be the chief implement used in this country down to the present day. The binder is a complicated machine and a number of principles introduced previously are incorporated in it, together with a mechanism which ties each sheaf up with a string band.

The standing corn is bent over to meet the cutter bar by the reel, which consists of horizontal slats on stays revolving in a vertical plane : the height of the reel and its position relative to the cutter

bar may be varied, its flexibility in this respect enabling it to act efficiently under widely differing conditions. The cutter bar carries fingers through which a reciprocating knife works : the speed of the knife is less than in the grass mower, and the stroke is longer, because of the greater ease of cutting ripe corn compared to grass. Having been cut the corn falls back on to a platform, which is approximately horizontal, but may be raised or lowered and tilted forwards or backwards as conditions require. An endless canvass, strengthened by narrow wooden slats, travels over the platform, moving the cut corn to one side, where it passes up an incline between two more moving canvasses : elevation of the material is necessary to carry it over the main travelling wheel. Being delivered by the canvasses at the highest point of the machine, the corn slides down an inclined deck on the side of the machine away

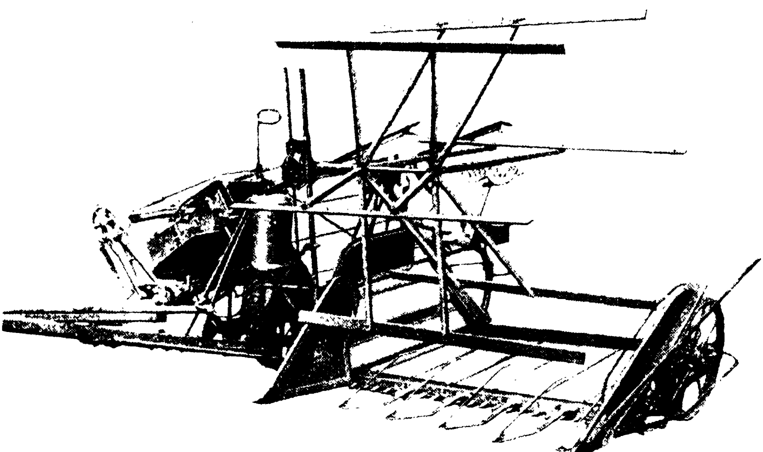


FIG. 22.—THE BINDER

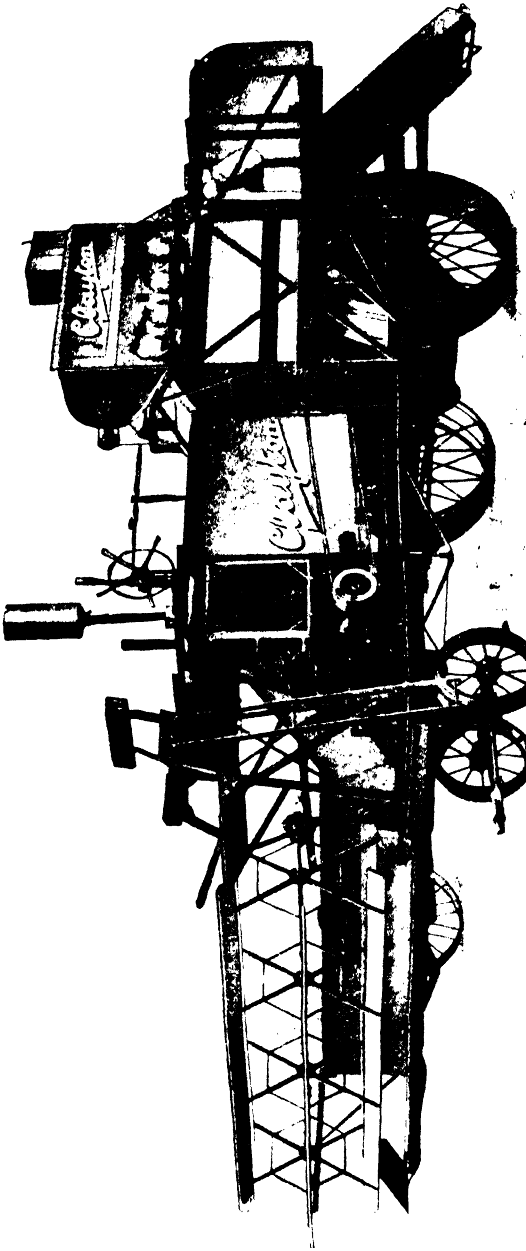
from the cutter bar ; here it is packed by rapidly moving arms whilst the butts are straightened by a board. The fall of the material down the incline is arrested by an arm, and when sufficient weight has collected the pressure trips the tying mechanism into action. The end of the string is held in a retainer, from which it passes on the outward and under sides of the sheaf in process of formation, below the deck, and through the eye of a large needle to the string receptacle : when the trip sets the needle in motion it carries the string round the inward and upper sides of the sheaf to the retainer, where it is caught, and the encircling of the sheaf is completed. At this moment two short knotter bills catch the double string near the retainer and, by performing a quick revolution, form a loop in them, the bills then opening and seizing the strings. At this stage three delivery arms throw the sheaf clear of the machine, and its weight draws the loop from the bills over the ends held by them, thus making the knot. Following this the

strings between the bills and the retainer are pressed against a short knife blade, which severs them, and the needle recedes below the deck again, leaving the end of the string in the retainer, whilst the short cut end falls out. The whole tying mechanism may be moved forwards or backwards by a lever, so that whatever the length of the straw, the band may be put in the middle of the sheaf. Normally the sheaf falls to the ground, but a sheaf carrier is usually employed to catch those deposited just after turning a corner and to carry them sufficiently far to ensure that the horses do not walk on them during the following round: the carrier consists of long tines which protrude outwards for catching sheaves, but otherwise are folded together below the machine, their position being controlled by a foot lever operated by the driver.

All the moving parts of the binder are driven normally by gearing from the main travelling wheel running in the centre of the machine, and though this is satisfactory under most circumstances, it has its drawbacks, for the force required in operation accentuates any tendency of the travelling wheel to skid. When the ground is soft considerable delays may be caused through this. Since the general adoption of the tractor, power binders have been introduced, and in these the moving parts are driven by an independent take-off, for which most tractors provide facilities. Besides saving skidding this method of drive has the great advantage that forward motion may be stopped and the mechanism may still be kept working until all cut material is cleared; this is a great help when dealing with laid and twisted corn. The power take-off must be fitted with a catch spring to break the transmission when an obstruction occurs, such as a stone in the cutter bar, otherwise serious breakages may result.

Horse-drawn binders have a width of cut of five or six feet and require three good horses, which can only be expected to work for about five hours; the common practice on all except very small farms is to use six horses in two shifts, and then about 10 to 12 acres are covered in a day. Where the corn is laid it may only be possible to cut along three, two, or even one side of the field, the acreage covered being reduced almost correspondingly. Tractors move more quickly than horses and are used with binders taking a width of up to eight feet. Such a combination may cover 25 acres in a day. Unfortunately the binder, in its working state, is too wide to negotiate a gateway, and when this is necessary the shafts have to be moved and fixed on the under side of the platform, the machine then travelling sideways.

The binder, being an intricate machine, demands considerable care, and should be thoroughly overhauled before each harvest. Good twine is essential as economy in this respect leads to many stoppages during work; a good crop needs about one $5\frac{1}{2}$ lb. ball per acre. Frequent oiling is essential, and special care must be taken to keep the canvasses dry, because they shrink on wetting, and if this happens when they are tightened they may tear. When



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left in the field over night the canvasses must be slackened and the machine covered with a cloth and sheaves. At the end of

harvest the canvasses should be removed, the working parts cleaned and oiled, and the machine put under cover for the winter.

Larger and more complicated machines have been developed in other countries to economize still further in labour : their function is not only to harvest, but also to thresh the corn, and there is little doubt that the cost of these operations may be very markedly reduced by their use. *In one type the ears of the crop are cut and threshed by the same machine, or after cutting they may be carted to a stationary thresher : the straw in this case is burnt or turned in by the plough. The "Combine Harvester" (Fig. 23) cuts the straw and may leave stubble but little longer than that of the binder : it is a heavy machine but its draught is within the capacity* of a tractor, its working parts being operated by a petrol engine incorporated in its design. The width of cut varies from 12 to 20 ft. and the area covered per hour from two to four acres. The corn may either be dumped in sacks or may be accumulated in a container on the machine, which is emptied at intervals into tank waggons ; the latter method has proved to be the cheaper. In some cases the straw is left in a windrow and is subsequently gathered by sweeps and stacked ; in other cases it is spread out ready for turning in with the plough. Another possibility is to hitch a baler behind the machine, but this has not proved very satisfactory, as it occasions considerable waste time. The tractor and combine can be operated by four men, or even three where the crop is light : the crop must be dead ripe and it is left for about a week or ten days later than the time when it would be considered ready to cut with a binder. An alternative method is first to use a machine that cuts the corn and leaves it in a windrow : rather a long stubble is desirable in this case, as then the windrow is kept well off the ground and dries very quickly : later a combine, fitted with a pick-up attachment in place of the normal cutter bar, takes up the windrow and threshes it.

These machines have proved their worth under extensive conditions of agriculture, which are characterized by two features—cheap land and dear labour : the latter now applying to this country, considerable speculation has arisen as to their desirability for our conditions, and in the last few years several have been used commercially with good results. It had been thought that our climate was too uncertain for their use, but this has been disproved, as it is found that they will work satisfactorily whenever a binder could do so : also, contrary to the previously prevailing view, they have proved capable of dealing with heavy crops, though the acreage covered is reduced. It appears that no more grain is lost by shelling than under our present methods : another important consideration is that good, though rather broken, straw can be obtained from them. The small size of many fields in this country is a serious drawback to the use of combines for though they can turn corners whilst at work as easily as can a binder, the double shift necessitated by passing through a gateway takes about eight hours. There

are a number of farms, however, where this could be largely avoided. A more important objection lies in the fact that in most seasons the corn as threshed in the field in this country contains about 20 per cent. of moisture, and has to be dried artificially for storage : machines are available for this but, though the work done by them is satisfactory, the cost is high, amounting to 40 per cent., or more, of the remainder of the cost of harvesting the grain. There is an undoubted future for machines of the combine type in this country but it seems improbable that they will ever become so universal as the binder is at present : they will probably be restricted to farms specializing in corn growing and particularly adapted for them.

THRESHING MACHINES.

Threshing Machines (Figs. 24 and 25) were introduced in the beginning of the Nineteenth Century and, despite the fierce opposition of agricultural labourers fearing loss of employment, soon became established over the older method of the flail. A threshing set is rather beyond the financial resources of a small farmer, and it would be uneconomic to purchase a machine where only small acreages are involved, so that it is common for contractors to own sets and to hire them to farmers. A set comprises a thresher, an elevator and a chaff cutter, together with the engine which functions in transport and as the motive power when the set is at work. Larger farmers often feel that the convenience of having a set of their own justifies the outlay, and the tendency is for more to purchase threshers now that their normal equipment includes a tractor and an elevator.

The corn to be threshed is fed to the drum from the top of the machine, the bands of the sheaves first being cut : in feeding, the ears are put in first, except where unbroken straw is particularly desired, when the sheaves are fed longitudinally. The drum revolves at about 1000 r.p.m. and consists essentially of eight ribbed steel bars which beat out the grain against stationary bars partially encircling it and forming what is termed the " concave " : the amount of the clearance between the drum and the concave can be varied to cope with different sizes of grain and other factors affecting the ease of threshing, the object being to separate all the grain without breaking any. Most of the grain falls through the concave, the straw passing out of the front of the machine over shakers, which allow what grain remains in it to fall through on to a collecting board : it makes its way down this to join the grain from the concave on the " caving riddle." The cavings, which consist of broken pieces of straw and leaf, ride over the riddle and out at the front of the machine, whilst the grain falls through to the second collecting board. Like the first, this slopes backward, and the grain travels down it and drops through an air blast from a fan to a series of sieves. The fan blows out the chaff which falls into a heap below the machine, whilst the sieves separate and deliver the coarser

material, or chobs (*e.g.* beans in wheat), to the side, the small weed seeds dropping through all of the sieves to the ground. From this, the first dressing shoe, the grain collects in a sump where it is picked up by the grain elevator, an endless band carrying buckets, and discharged into the awner and chobber : this consists of revolving knives and bars, with adjustable clearances. It removes any chaff still adhering to the grain and also the awns of barley. Thence

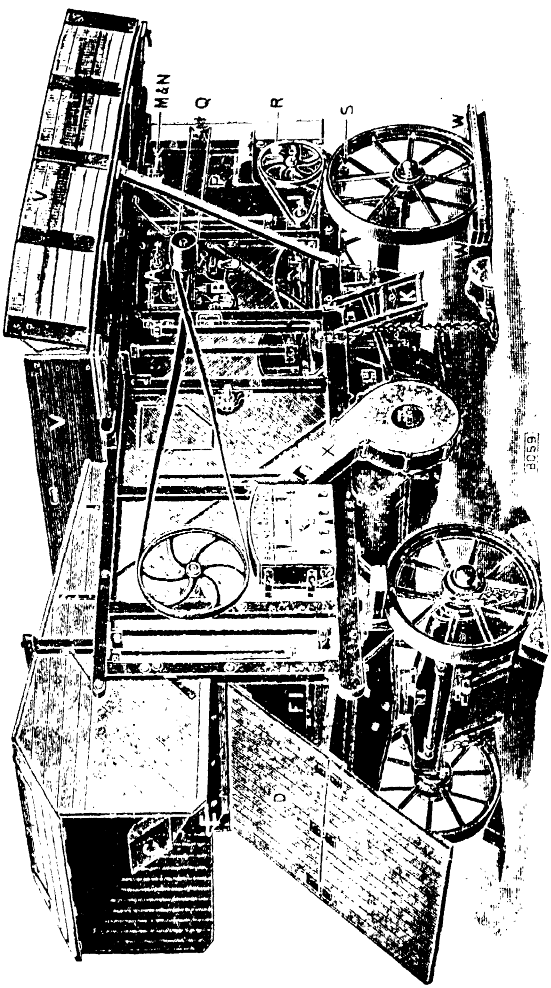


FIG. 24. THRESHING MACHINE (NEAR SIDE).

A, threshing drum.
B, concave.
C, straw shakers.
D, straw board.
E, upper collecting tray.
F, eaving riddle.
H, lower dressing shoe (1st dressing app.).
J, crank for driving dressing shoes.
K, 1st fan.
M, awner.
N, chobber.
P, 2nd dressing shoe.
Q, 2nd fan.
R, rotary corn screen.
S, corn spouts.
VV, guard boards round platform.
WW, wheel chocks.
X, chaff bagging apparatus.

the grain passes to the second dressing shoe through an air blast from another fan, material removed passing back to the first shoe, and finally to the rotary screen. The screen is a cylinder with a periphery of wires through which the grain finds its way to the sacks : the wires are closer together at the end where the grain

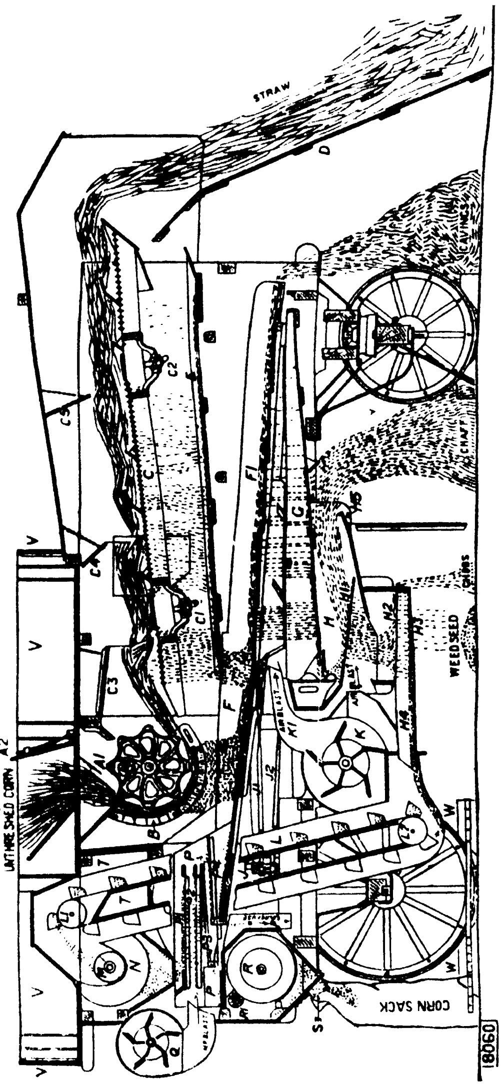


FIG. 25.—SECTION OF THRESHING MACHINE. LONGITUDINAL VERTICAL SECTION.

enters and become further spaced towards the other end, so that several grades are obtained, the smaller grain passing through earlier. The screen is adjustable in the spacing of its wires, but should not be tightened whilst running, nor with grains held between the wires, because of the liability of bending them. One of several paths may be chosen for the grain after it leaves the elevator : it may pass through all the cleaning and grading devices mentioned, or it may be short circuited past one or more of them, in some cases it being sent straight from the elevator to the sacks.

The straw is usually built into a stack, an elevator (Fig. 18), driven by a belt from the thresher, being placed to catch it as it falls from the shakers ; the elevator need not be in a straight line with the thresher, pulleys for the belt allowing angling up to 90°. Another common practice is to use a "Chaff Cutter" (Fig. 26) which, again, is driven from the thresher : the straw is fed by hand into the mouth where cogs seize it and present a tightly pressed

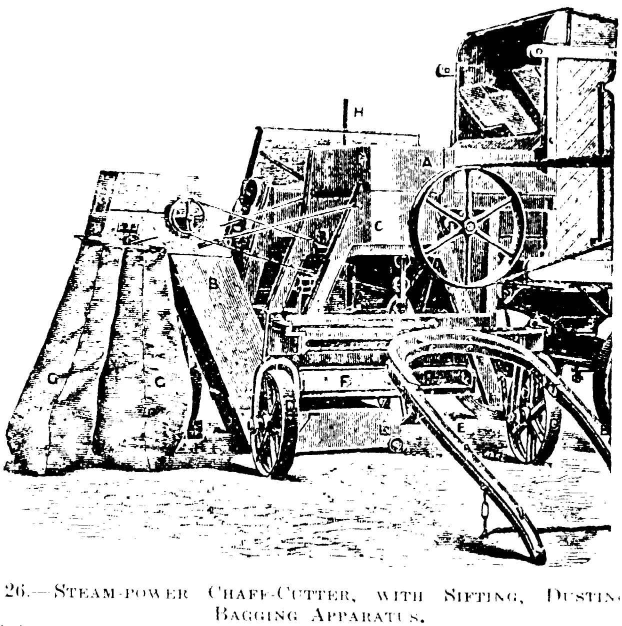


FIG. 26.—STEAM-POWER CHAFF-CUTTER, WITH SIFTING, DUSTING, AND BAGGING APPARATUS.

A, driving pulley, on which runs belt from thresher, or direct from engine.
vator trough, or bagger.
D, fr
E, shafts.
F, riddle for sifting out the imperfectly cut material.
G, chaff bags.
Y, lever to stop and feed.

bundle to large knives on a rapidly revolving wheel, the straw being cut into lengths of about one inch. Chaff cutters used with threshers are fitted with riddles to remove dust, the chaff being elevated and fed to sacks as illustrated : whilst chaffing saves later

work, it slows down the speed of threshing because the cutter cannot take the straw as fast as it can be threshed, and it is usually considered that the process reduces threshing speed by about 25 per cent. Balers provide a third method of dealing with the straw; they receive it from the shakers and their action is similar to that of the packers and knotter of the binder, two bands usually being put round each bundle.

Contractors send two men out with a set of threshing tackle, one of whom feeds the corn to the drum whilst the other exercises general supervision over all the machinery; seven or eight other men are required, of whom two or three are employed on the corn stack, two or three on the straw stack, one or two cutting the bands of the sheaves, one clearing the chaff and cavings as they accumulate, and one taking off, weighing and tying the sacks of grain. In addition some attendance is necessary to supply the engine with coal and water. The amount threshed per day is usually 300 to 400 bushels with wheat and barley, and 400 to 500 bushels with oats. With good organization, and when men are paid by piece-work, much better outputs can be achieved; where threshing is done straight from the stook, however, less will be accomplished because of the time wasted in changing carts between loads.

In some other countries the above rates of threshing are greatly exceeded, principally through the use of machines of larger capacity

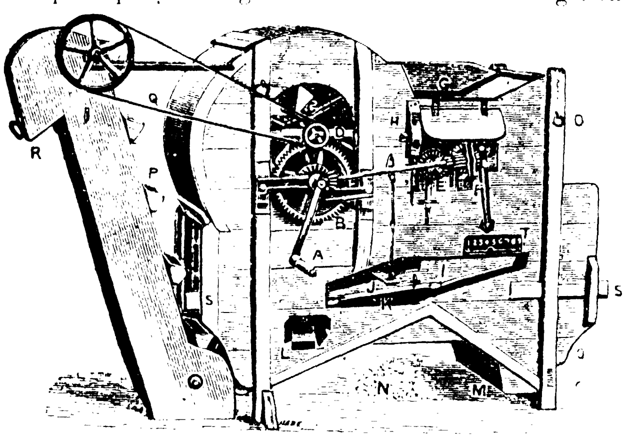


FIG. 27. CORN WINNOWING OR DRESSING MACHINE.

handle.
main wheel
fan.
pulley on fan axle to drive elevator.
wheel driving large roller.
wheel driving small roller.
hopper.
screw to regulate feed.
riddle frame.
riddles.
K, screen under riddle.
L, spout from which stones, sticks, &c., are delivered.
M, tailing corn.
N, screenings.
O, chaff.
P, elevator cups.
Q, strap to drive elevator.
R, spout where dressed corn is delivered into sacks.
S, lifting handles.

with more width of drum. The type of drum too is different, having numerous short protruding pegs, which thresh the corn against others in the concave, between which they run. Whilst peg drums thresh well, they are unpopular in this country because they break up the straw to a considerable extent.

Modern threshing machines do very good work and yield a sample of grain which is clean and graded sufficiently for sale in most cases, but where special lots are being sold at high prices for seed, and in the case of malting barley where great uniformity is important, further dressing may be carried out. For this the "Winnower or Dresser" (Fig. 27) is employed. This is a hand-worked machine which incorporates no new principles over and above those of the thresher. Grain is fed into it from a hopper in its upper surface, a blast of air blowing through the stream and removing any chaff ; sieves then grade the grain into three lots which are delivered at different points. The sacking attachment, as illustrated in the figure, is convenient and economises labour, but is not always used. The machine is small and the whole operation is carried out in a barn, so that it is independent of the weather ; three men should dress about 200 bushels in a day.

CHAPTER III.

TILLAGE.

TILLAGE means the cultivation or working of the soil with implements for the benefit of the crops growing or to be grown upon it. The gardener tills the garden with fork or spade or hoe just as the farmer tills his fields with plough or cultivator or roller. Indeed, there is no better way for a student to grasp the first principles of tillage than by cultivating a garden, especially if two or more types of soil are represented in it. It matters not how small the plot or garden be so long as the work be done by the student himself at all seasons of the year and the effects, immediate and after the lapse of days or weeks, be carefully noted so that not only the effects of the tillage itself but also of the subsequent "weathering" may be stored in the memory as experience. It is doubly helpful if upon this experimental plot the student deliberately carries out acts of tillage which he knows, or he believes to be, harmful. Some of these may well prove to his surprise to be beneficial, especially if he is fortunate enough to be working upon a soil with which he was not previously acquainted ; for correct practice upon each soil type is different. Such experiences will be invaluable when he begins to cultivate with field implements upon a farm scale. It is comparatively easy to discourse upon tillage and the theories of tillage but nothing can take the place of careful observation on the land and the experiences accumulated therefrom.

Whilst in the main tillage is the work of implements the natural agencies by which the texture of soil may be ameliorated must

always be kept in mind. Darwin in his observations upon earthworms showed how great is the work of these in elevating soil to the surface, literally turning it over, and by so doing loosening it, mining it, providing passages for air to enter and gases to escape and for the movement of water. In fact it is true to say that the work of worms in the tillage of grassland exceeds many times that accomplished by man. And to a lesser extent their work is important on arable land. Frost, by its effect upon the water contained in soil, causing it to expand when changed to ice and forming planes of partition between particles of soil, is another natural agency of supreme importance in successful tillage. The heavy land field, ploughed early in winter and well frozen, responds easily to cultivator or harrow in spring in the production of an easy seedbed. A third natural agency of supreme importance in obtaining a correct texture is that due to the expansion of soil, especially clay soil, when moistened and its contraction when dried. A clod of clay or a clay furrow contracts slowly and " sets " hard like concrete when dried in the sun. When the same clod, or the same furrow, is moistened by rain the outside quickly becomes wet, whilst the inside may remain dry or moisten more slowly. The outer layers expand immediately they become wet whilst the dry centre remains unchanged. This sets up stresses which result in the wet outer layers fracturing or splitting from the dry centre so that they can afterwards be easily shattered by harrow or cultivator.

The purpose of this chapter is to consider the tillage of the soil brought about by the use of implements.

The objects of tillage are :—

1. To modify the texture of the soil.
2. To modify the content of air.
3. To modify the content of water and the temperature.
4. To kill weeds.
5. To facilitate the killing of insects in the soil.
6. To incorporate crop-remains and manure with the soil.
7. To make plant food available.
8. To encourage germination and root growth.

1. To modify the Texture of the Soil.—The first and most important object of tillage is to alter the texture of the soil so as to make it more suitable for the purposes of the cultivator. It would be true to say that the modification of the texture is the primary object of tillage, because air content, water content, weed destruction, seedbed preparation, and in fact all the other purposes of tillage depend upon modifications of texture. The soil proper consists of soil particles, great or small, some acting as single unit particles others grouped together. These particles or groups of particles are surrounded by soil spaces. The soil spaces in their turn are occupied partly by air, partly by water. All of these have their influence upon soil texture, and tillage is concerned as much with the soil spaces as with soil particles.

Before cultivation starts the soil of an arable field has generally been compacted by the weathering of the soil, the beating of the rain, by the preparation of the seed-bed, by the intercultivation and harvesting of the crops. By these agencies the soil particles have been compacted tightly together and the soil spaces, though still present, have been reduced in size. In some cases, as for example when the crop has been carted off in wet weather or the land has been trodden in wet weather by folding sheep, the soil particles are stuck together and the soil has lost its friable texture. Clay soils exhibit these characteristics in their worst form and it will be well to consider how the texture of such soils may be modified by cultivation so as to fit them for the growth of plant roots and of crops.

Heavy clay soils contain a relatively small proportion of the large coarse particles, which help to give friability to a soil and a relatively large proportion of finely divided material which produces the sticky character of these soils. These soils become sticky and pasty when " worked " in a wet condition. They become plastic when worked by the brickmaker. When ploughed in wet condition the texture of the furrows bears a close resemblance to that of putty. If these furrows are then dried they bake and set with a hardness that resembles concrete. The texture of the soil in any of these conditions is useless for plant growth. How then can it be modified so that it may become suitable? What are the optimum conditions for plant growth? The optimum texture of a soil for plant growth should be similar to the mould which a gardener uses in his flower pots. It should have a granular, crumb-like structure resembling breadcrumbs. In this condition it is easily penetrated by plant roots; it is sponge-like for holding water and also for giving up its water to plant roots and it is easily penetrated by air and plant roots.

These conditions can be obtained by a combination of tillages carried out at the right time so as to take advantage of the natural weathering agencies. Ploughing is generally the first tillage. This by cutting the soil into rectangular slices and turning them over exposes the soil in a rough condition to the action of the weather. Cultivating the ploughed ground, especially if done by steam or tractor with powerful cultivators breaks the rectangular plough-slices and exposes the land again to " weathering " agencies.

After the ploughed depth of soil has been well weathered (by frost and thaw, or by drying and wetting) the soil becomes friable and the rough clods, if then moved with the cultivator or harrow, or pressed with the roller may shatter to pieces forming the crumb-like or granular structure, which is desired.

Sandy soils are much easier to break in pieces without the help of the weather than clay soils. When ploughed, the furrows in addition to being cut and turned are frequently shattered by the operation of the plough, and the plough furrows, if cultivated at the right time, can be broken into a crumb-like structure by tillage

implements without waiting for the action of the weather. These sandy soils are, however, often loose in character and liable to be too open, consequently they require to be properly rolled in order to obtain the requisite firmness.

2. To modify the Content of Air in the Soil.—The size and distribution of the air spaces in the soil is controlled by weathering, thus rain tends to beat down and consolidate the soil, whilst frost tends to lift and loosen it. Tillage also regulates and modifies the soil spaces and so modifies the content of air in the soil. When land that is compact and solid after the growing of a crop is ploughed it is easy to see that the ploughed furrows as they lie in position are exposed to the air both on the surface of the field and also on the under surface of the furrow, for after ploughing with the common plough the furrow rests upon the subsoil on one of its edges. The distribution of air in the soil after one ploughing is, however, by no means complete for the core of the furrow may not be exposed at all. If a second ploughing is given or if the land after the first ploughing is cultivated the land is first lifted and shattered and then allowed to fall in this shattered condition upon the subsoil. This action may be likened to the taking of a deep breath by the soil, inspiring the air as the cultivator tines lift the soil, expiring as the shattered soil falls back into position. The harrow by the combing of its tines through the soil and the breaking of the smaller clods still further exposes the soil to the air, but in so far as the action of the harrow is one of consolidation it tends to reduce the soil spaces and so the air content of the soil. The roller by consolidating the soil reduces the soil spaces and so squeezes out some of the air contained in it. Other implements of tillage may be used to influence the air-content of the soil in various ways—the cultivator tines lift the soil, expiring the air as it falls back upon the subsoil in a shattered condition ; the harrow, by the combing action of its tines as they pass through the soil, breaks the smaller clods and exposes their inner portions to the air. By this breaking of the smaller clods and by the consolidating action of the implement itself the finely divided soil settles more compactly so that the larger air spaces left by plough or by cultivator are reduced in size. The action of the roller still further breaks the small clods and consolidates the whole of the surface soil.

3. To modify the Water Content.—Tillage is concerned with the relationship of soil to the moisture it contains in many respects. It may be necessary to dry the soil for the destruction of weeds, in which case the production of a rough broken surface is desirable so that a larger surface area of moist soil is exposed to the action of drying winds and sun. This drying is increased by the presence of large soil spaces under the surface, because air passes readily into and out of these and in doing so carries moisture, which has evaporated from the soil below ground, with it. This drying of roughly broken ground is well illustrated when a bare fallow is ploughed for the first time in late spring or early summer. The air circulates freely on all sides of the furrow, which in dry weather rapidly dries through. At other times it is

desirable to prevent evaporation and to conserve moisture for the use of growing crops. In this case the land must be worked to a smooth level surface. The large hollow spaces below the surface must be obliterated by tillage implements so that air does not circulate too freely and dry the ground. The need for this is well illustrated in preparing a seed-bed on folded land in late spring. If the land is ploughed and left for a few hours the furrows are dried through in very short time. If each day that portion of the field which is ploughed is immediately rolled and harrowed or well disced some of the moisture will be retained.

Sometimes it is desirable to make moisture in the lower depths of the soil available near the surface as for example when small seeds are being planted. In this case the soil requires to be in a finely divided granular condition so that the granules may pack closely together among themselves and with the subsoil. Then consolidation by rolling brings them into close contact so that moisture can pass freely up through the whole and to the seeds drilled shallowly below the surface of the land.

At other times it may be desirable to prevent loss of water by evaporation from a firm moist surface. In this case contact between the surface inch or so of top soil and the lower depths must be broken by hoeing or shallow cultivating. Then the loosened surface dries out and hinders further evaporation of soil moisture.

Sometimes it is desirable to facilitate the drainage of water through the soil in which case the land should be left in deeply broken and rough condition. The use of a deep winter furrow by the "common" plough, which is designed to leave an unbroken furrow, facilitates drainage and the land will be dry for working in spring. Occasional subsoiling or very deep steam-cultivating may be used to break up a plough pan and allow water to percolate more freely into the drains below. At other times it is desirable to put the soil into a condition to hold moisture for the growth of plants and especially so in the preparation of seed-beds. In this case a finely divided crumbly structure is required so that the moisture may be held within it as in a sponge. This condition is the typical condition required for seed-beds, and not the least important reason for this condition is to facilitate the retention of rain water for the germination and growth of the crops.

4. **Weed Destruction.**—The destruction of weeds is one of the most important objects of the arable farmer. Careful tillage is the weapon whereby this can be done economically. Weeds from the farmer's point of view may be classified into annuals and perennials. Annuals, of which charlock, poppy, chickweed and groundsel are typical examples, are characterised by very rapid growth. They germinate flower, set seed and die within one year. They produce a very large quantity of seed if allowed to grow to maturity, so that succeeding crops become smothered by them, but generally they can be easily destroyed especially when young. All annual weeds may be destroyed by burying beneath the surface of the soil,

provided every growing shoot is covered. If, however, the smallest shoot is allowed to project above the surface, it immediately recommences to grow. It is therefore important, when digging or ploughing, to bury every green leaf. Annual weeds may also be killed by dragging them out by their roots and leaving them on the surface to be dried out by the sun and wind. This method is only successful in dry hot weather. In moist weather they strike root again very quickly. Baby seedlings are killed very quickly by this method but older plants are more difficult to kill because their roots are long and it is difficult to shake every root free from soil. The harrow is the principal implement used for this purpose. Thirdly, all annual weeds are killed when cut just below the junction between stem and root. The severed root dies because it is unable to produce buds and shoots; the stem dies because, having no fibrous roots, it is unable to obtain water. This is the manner by which weeds are killed by hand- or horse-hoe. If the hoeing is too shallow, so that the weeds are cut above the junction of stem and root, buds form on the piece of shoot attached to the root and the weed grows as quickly as ever. This is a very common fault in hand-hoeing, especially when the ground is hard. If the hoeing is too deep, much fibrous root is left attached to the stem and this may be sufficient to collect and supply moisture and so prevent the plant from drying out. This condition is sometimes obtained with horse-hoeing especially in damp weather.

The multitude of seeds, which annual plants produce, is however the greatest trouble with annual weeds. Every effort must be made on the one hand to reduce or prevent seed formation. On the other hand either after one crop is harvested or in the preparation of the seedbed for the next crop opportunity should be given by suitable tillages to encourage these dormant weed seeds to germinate so that the seedlings may be easily killed.

Perennial weeds grow comparatively slowly but unlike annuals they do not die after producing seed but live for long periods. Some are propagated vegetatively when parts of their stem or root are broken off and embedded in the soil. Some underground part of their structure, sometimes root, sometimes stem, is thickened and acts as a storehouse in which food material is stored for the future needs of the plant. These thickened parts are especially difficult to destroy, for they are not killed by burying in the soil. They are only killed with difficulty by drying out after being dragged to the surface, because they hold moisture tenaciously. Such weeds cannot be killed by severing the stem and root with the hoe. One part and sometimes both parts will grow again if this is done Special methods, therefore, must be adopted for killing perennial weeds, and different perennial weeds may require different treatment.

The perennial weeds may be subdivided into four classes :—(1) the true tap-rooted weeds, such as the dock and the dandelion, which are provided with long tapering, vertical roots ; (2) the false

tap-rooted, such as the creeping thistle, the convolvulus, the coltsfoot and knapweed, the underground thickened parts of which are not roots but stems ; these have vertical stems which grow through the surface soil from a horizontally branching system situated below the depth of plough furrow ; (3) rhizomatous weeds, such as couch, (*Agropyrum repens*), and some forms of bent and twitch (*Agrostis stolonifera*), have shallow horizontal stems growing to the depth of the plough furrow but rarely below ; and (4) bulbous-rooted plants, such as wild onion, onion-couch and some buttercups. The dock, which is much the most important of the true tap-rooted weeds, generally gets established from seedlings in growing corn crops. After the corn is cut they are small plants, which can then be killed easily if the stubbles are quickly broken, but if the stubbles are left undisturbed, as for example when a clover crop has been planted in the corn, they quickly grow into large plants. If the clover is cut twice for hay, there is little chance for the dock to set seed during this year, but when the clover is broken up and the field cropped with wheat, the docks send up flowering stems which produce great crops of seeds some of which are shed on the ground and some are carried with the straw to come back to the land in the dung. Docks present two favourable opportunities for eradication by tillage, firstly by quick cultivation of the stubbles after harvest, and secondly by the efficient use of the cultivator in preparing a seed-bed for the root-crop in late spring, whereby the roots of the dock may be brought to the surface and left to dry out for some little time. Failing these methods docks can only be eradicated laboriously by hand-digging or by bare or bastard fallowing.

False tap-rooted weeds are propagated chiefly by vegetative growth. Propagation by seed is less important either because they produce few fertile seeds or because the seedlings are small and do not easily establish themselves. Their main stem-system is below the usual depth of ploughing, though often much of it is only just below this depth, consequently there is little chance of complete and immediate eradication. The best policy for their destruction is one of attrition, a gradual weakening of their strength by continually cutting off their shoots soon after they have appeared above ground. This may be accomplished by the use of any horizontally-bladed implements, such as the plough, the broadshare, or the hoe. Cultivators with narrow tines are of little use for destroying such weeds. Another valuable tillage-method for this purpose consists of ploughing deeply once during the rotation in preparing for the fallow crop. This results in much of the stem-system, growing just below the normal depth of ploughing, being brought to the surface. From this position it can be pulled out by cultivator and harrow and eventually killed by drying out.

Rhizomatous weeds are perhaps the most troublesome of all to the arable farmer because they are difficult to destroy, and because they spread very rapidly. They cannot be killed by burying, they are killed with difficulty by drying out and every time a plant is

cut or broken it results in the formation of two plants instead of one. The best policy is to aim at complete extermination. A half-hearted policy is fatal because a field partly cleaned of these weeds will be restocked within the year. The method to be adopted consists of working these weeds to the surface, then collecting them and finally burning them or carting them off the field. It is rarely possible to destroy them by drying out in the sun except during a long bare fallow.

Bulbous weeds do not lend themselves to any general methods of destruction. Each type must be dealt with by separate methods.

5. **Pest Control.**—Tillage may be used to facilitate the killing of insects by disturbing their winter quarters, by burying them deeply in the ground or by exposing them to the attacks of birds. Starlings, rooks and other birds pick up many wireworms and other insects whilst following the plough and other tillage implements.

Tillage may also be used to limit the activity of insects in the soil. The heavy roller by consolidating and compacting the surface soil is often used when wireworm are attacking a cereal crop, not to crush and kill the insects, but to tighten the soil so that the insects cannot move so freely through it.

Crop remains, farm-yard and artificial manures require to be well mixed with the soil so that they may be made available to the growing crops. For incorporating crop remains and farm-yard manure the plough is the best implement because of its inverting action on the soil, but generally it is not desirable to plough in artificial manure. Artificial manures are preferably worked into the soil by cultivator or harrow and other implements designed to stir and mix the soil, so that the manure may be uniformly distributed throughout it.

Tillage by the processes enumerated above leading to the better distribution of air and water in the soil also causes dormant and insoluble plant food to become available for the use of plants.

Finally tillage is designed to make the seed-beds suitable for the various crops to be grown; suitable by its supply of air and water for germination, suitable by its texture for the free growth of plant roots throughout the surface soil; suitable by its water-content to supply water to the growing roots, and suitable for the supply of plant food.

COMBINED TILLAGES FOR THE CLEANING OF LAND FROM WEEDS.

The Bare Fallow.—This is a practice in which the land is left uncropped throughout a whole year, during which it is cultivated for the purpose of killing weeds.

It was formerly much more frequently adopted in England than at present. It formed an essential part of the three-field rotation under the Manorial System. In primitive agriculture it has been and still is commonly practised. In Canadian and Australian wheat farming it forms part of the ordinary system

though its value, especially in Australia, is mainly for the collecting and storage of rainfall in the soil. With the improvement in tillage implements and the intensification of farming the practice is no longer used on light or medium soils in Great Britain, but it is still the most complete method of cleaning heavy land of perennial weeds.

In its operation many of the rules of good tillage are broken because it is not desired in the first instance to fit the ground for the growth of plants but rather the reverse ; to kill all growing plants in the soil. In a typical case a bare fallow on clay land starts with the ploughing of the land in spring—not in autumn or winter lest frost should break down the furrow and produce a tilth too soon. If the ploughing is done with horse teams a time will be chosen when the land is wet and unfit for other tillage operations so that when dry weather follows the furrow dries harshly and does not crumble. When horses are the source of power, the next operation will be the second ploughing of the field in May or June. In this the furrows are not crosscut but simply reversed. The purpose of it is to expose another surface of the original plough furrow to the drying action of sun and air, and again to break the contact of the furrow and the subsoil. After another interval of two or three weeks, by which time the furrows will have dried and become more brittle, the land is ploughed a third time. On this occasion the ploughing is across the furrow so that the original furrows are broken into great clods with the couch and other weeds imbedded in them. The sun and wind dry these clods and the weeds at the same time. The surface soil in a cloddy condition is severed from the subsoil so that no moisture can rise from below and in the event of rain the water quickly drains through to the subsoil leaving the clods dry. The killing of the couch and other perennial weeds in the clods is completed by continually turning them over in dry, hot weather with long-tined drag harrows or cultivators so that clods become completely parched and the weeds are killed by being dried out. It will be realized that the efficiency of this method of killing couch and other perennial weeds depends on the complete dessication of the plants. If only a tiny portion of the plant retains moisture it will recommence growth as soon as rain falls. Therefore the best use must be made of any spell of dry, hot weather to complete the drying of the weeds.

Up to this point little or nothing will have been done to eliminate annual weeds, the seeds of which have been lying dormant in the dry clods. The frequent cultivations will gradually have broken down the large clods, and rain, if this has fallen, will have caused these to break into a finer texture, so that towards the end of summer the soil becomes more retentive of moisture. As soon as sufficient rain has fallen to make the soil really moist weed seeds begin to germinate freely. These are destroyed by the last operation of the bare fallow, which consists of ploughing the land once more either just before or just after harvest so that the land is fit for

cropping with wheat or some other crop in early autumn. Thistles and other weeds of this type, growing below the depth of ploughing, will also have sent up stems above ground towards the end of summer and these too will be cut and killed by the final ploughing.

The operations comprising the bare fallow have been described in relation to horse-power, because the bare fallow was so essentially a feature of farming in the early days. It should be recognized, however, that steam-power, where this is available, is more efficient for the purpose of fallowing clay land. The reserve of power enables the land in the first place to be broken up to a good depth with the plough, and the long-tined cultivator hauled by steam enables the subsequent breaking and stirring of the land to be carried out more efficiently than with horses or with tractors.

The Bastard Fallow.—This practice, sometimes called half-fallowing, may be substituted for the bare fallow after a catch crop or other crop has been cleared from the land early in summer. It is frequently used on a dirty piece of " seeds " after the first crop of hay and it naturally follows the harvest of a silage crop such as beans, oats and tares in July. Substantially the operations are the same as those in a bare fallow but have to be carried out during a shorter period of time. The land should preferably be ploughed first to a sufficient depth to insure the turning over of all couch stems. In some cases it may be too dry and hard for ploughing. In such cases a double steam cultivation is the best practice. The land after being broken up is left for the weeds to become partly dried out, the length of time depending upon the character of the weather and pressure of other work. Then the field is thoroughly stirred, preferably with a double steam cultivation, which may have to be repeated. If the weather is favourable the weeds are dried out and killed as in the case of the bare fallow. The land may then be prepared for autumn cropping by methods similar to those following a bare fallow.

Bastard fallows have some advantages and some disadvantages over bare fallows. They enable a partial or catch crop to be harvested instead of the land being left uncropped and idle for the whole year. The ground before tillage operations commence will have been dried by the growth of the catch crop so that the weeds are more quickly dried out when it is broken up. Further, the weeds themselves, before tillage starts, will have been weakened by growth in competition with the catch crop and by being cut off when this was harvested. On the other hand although the bastard fallow is made immediately the crop is cleared and at a time when the weather is often hot, July and August are by no means universally dry months. Indeed they are frequently wet. The bastard fallow may then be an ineffective method for completely killing couch and other perennial weeds. In comparison with this the bare fallow is frequently completed, so far as killing couch is concerned, by July in years when May and June, generally dry months, have been favourable. Lastly the bastard fallow gives little

opportunity for the germination of weed seeds and the subsequent killing of the seedlings, consequently the following crops may be heavily stocked with weeds of this type.

Autumn Cleaning.—The two practices just described for the cleaning of the land from weeds depend for their success upon the complete drying out of the perennial weeds, especially of the rhizomatous weeds, whilst these remain partially or completely imbedded in the clod. Advantage is taken of the best drying weather of the summer to perfect these purposes. In " stubble " or autumn cleaning and in spring cleaning, an entirely different principle is brought into play. The weather during the time occupied by these practices is less certain and less favourable, so that if reliance was placed upon killing the weeds by drying out alone, many would escape destruction. Weed destruction in the case of autumn cleaning and spring cleaning depends firstly upon complete separation of the weeds from the soil and then destroying them by burning or by carting off the field.

Autumn cleaning, as its name suggests, consists of cleaning the land in autumn between the time when the corn crops are harvested and the advent of excessive autumn rains or the pressure of work involved in harvesting the root crops. The practice is carried out in a series of stages. The first consists of separating a comparatively shallow depth, three to four inches of the surface soil in which most of the weeds are growing and from which the stubble protrudes. This may be done by one of several implements. The most generally used is the plough. By this complete separation of some three or four inches of soil may be obtained, but the surface is turned over. The effect of this is to bury much of the weed, which subsequently has to be again worked up to the surface before it can be eliminated. Ploughing also has the disadvantage that even when motor- or steam-power is used it is comparatively slow. For autumn cleaning speed is important because time for efficient work is short. The cultivator is frequently used for breaking the land especially when steam-power and when tractor-power are employed but with these the surface soil is broken away from the subsoil at irregular depths. Frequently with steam- or tractor-power too great a depth of soil is broken, so that the subsequent separation of the couch is well-nigh impossible in the short time available. Or if the cultivation is shallow then much weed is missed and much is broken in pieces The best implement with which to engage in autumn cleaning is some form of broadshare. For horse purposes the old Kentish broadshare is ideal. Bentall's broadshare, developed in the middle of last century, was a splendid implement for the purpose. In those days it earned for itself the reputation of being a horse-killer, but this disadvantage disappears when it is linked to a tractor. Ransome's stubble breaker is the most modern development of this type of implement and is very efficient when operated by motor-power. The broad share is essentially useful for autumn cleaning because the land is so completely cut by the wide share that no vertically growing

weed escapes and because it can be set to make a uniformly shallow cut three to four inches below the surface. Further, the ground, instead of being turned as with the plough, is left in loose ridges which facilitate the drying of the soil and the weeds as well as the drainage of rain if this chances to fall. The second stage of autumn cleaning consists of separating the weeds from the soil. If the land has been broadshared and left in ridges this is easily accomplished by the use of heavy harrows. If ploughed the land must be cultivated once or twice to break the furrow and to work the weed to the top from which it is finally separated by the heavy harrows. The third operation consists of collecting the weed by the use of the chain harrow or the pitch pole harrow and finally forking together by hand. Lastly, if the weather is still dry the weed may be destroyed by burning or alternatively it may be carted from the land. When the stubble is reasonably clean one operation as described is sufficient to destroy most of the perennial weeds, but in cases where the stubbles are choked with them the operation will need to be repeated. In this case the plough should be the first implement used. This should be for the purpose of ploughing to the surface the weeds buried in the deeper layers of the soil. After this is done the operations should be repeated as previously described.

In districts where harvest is sufficiently early the autumn cleaning of the stubbles, especially on light and medium soils, offers great advantages to the arable farmer. These advantages may be summarized as follows: The weeds after growing through the year in competition with the crop and subsequently cut off at harvest are in a weakened condition. If left untouched till winter ploughing they rapidly gain strength with all the plant-food moisture, sun and air which the soil and natural agencies can supply. The land is usually dry and friable owing to the withdrawal of the moisture by the previous crop, consequently the separation of the weeds is easy. Land, efficiently cleaned in autumn, can be quickly prepared for cropping without danger of the loss of moisture which cleaning in spring involves. Consequently crop failures are less common and better crops are secured. The advantage of autumn cleaning as compared with spring cleaning is specially marked when sugar beet is the following root crop, since this requires to be planted early in the spring. Finally, autumn cleaning results not only in the destruction of perennial weeds of the rhizomatous type and the weakening of the false-tap rooted weeds like thistles by cutting off their stems just as they recommence growth, but it also results in the destruction of immense numbers of weed seeds. These, dormant in the soil, are made ready for germination by the aeration consequent upon the autumn tillage, with the result that many of these germinate so soon as they are well moistened by autumn rain and are automatically destroyed by the autumn or winter ploughing of the field.

Spring Cleaning is the term given to the cleaning of land from

couch and other weeds in the spring in preparation for root crops. It is a suitable operation for light land and in some seasons for medium land especially for late-planted roots, but it is rarely successful upon heavy land. In a wet season it is impossible to eliminate the weeds from heavy land, and in a dry season the cleaning operations spoil the texture and the land becomes too dry before the sowing is completed. The procedure for spring cleaning commences with a winter ploughing deep enough to be below all strands of couch. By this operation the weeds are buried and they lie dormant for some time. The land is left in this condition until it begins to dry in the spring and the weeds have begun to grow through again. It is then ploughed a second time. If the weeds are badly matted the second ploughing should cross the furrow, but if there is only a small quantity it is preferable to turn the furrow back and not to cross-plough because the latter operation tends to cut the couch in pieces and so multiply the plants. The effect of the second ploughing is to bring the weeds again to the surface of the ground and to help to dry the ground. Cleaning is continued in dry weather by using first the cultivators two or three times and then the harrows to work the rubbish on the top and to shake it free from the soil. Finally the rubbish is collected by chain harrows and forks, and then burnt or carted off the land. In cases where the field is badly infested with weeds it is necessary to plough again and repeat the cleaning operations till all perennial weeds are removed. But reliance upon spring cleaning for ridding the land of weeds, when tractor- and steam-power are available to supplement that of the horse, is bad farming practice at any rate in the drier districts of England. The best time for weed destruction is on the stubble immediately after harvest and in some seasons cleaning may be started as soon as the corn crop has been cut and shocked, provided the shocks have been placed in rows. This procedure is specially advantageous when showery weather prevails at harvest time and work in the harvest field has to be suspended. Under these circumstances good work can be accomplished by working the land between the shocks with horse or tractor.

Combined tillages used in the preparation of seed-beds for planting and for intercultivation are not separately discussed here. They will be described in their appropriate places under the section dealing with crops (p. 191).

CHAPTER IV.

DRAINAGE.

LAND-DRAINAGE dates from the beginning of tillage farming, and history contains a wealthy store of knowledge about this and its complementary subject, irrigation. These were practised by Egyptians and other nations in very early days. The Roman classics make frequent reference to the subject. Virgil, Cato and

others refer to the employment of open ditches for the removal of drainage water. Columella describes both open and covered drains; the latter being filled with stones or with fascines made from twigs and branches to provide channels for the underground water.

The practice of modern drainage may be said to have commenced in the seventeenth century. In the early part of this century Oliver de Serres, the French agriculturist, and Capt. Walter Blith, who wrote "The Improver Improved," discussed the problems and practices of land drainage, but at this period most systems of under-drainage were short-lived because of the lack of suitable material with which to construct underground channels for permanent drainage. Stones, chalk, fascines, straw, etc., which were commonly used, answered satisfactorily for a few years and then gradually became clogged with silt, leaving the wager-logged condition of the land worse than before. Consequently drainage from this period onwards was largely confined to surface drainage, and no important progress was made for a century.

In 1763, Joseph Elkington inherited a Warwickshire farm from his father, and finding it poor and extremely wet proceeded, with great enterprise and careful observation, to study the causes of wetness and to execute drainage works. His efforts were most successful. He discovered that the major cause of the wetness of his land, and of other neighbouring farms, was due not to direct rainfall, but to underground water, carried through porous layers in the soil seeping upwards to the surface on the lower fields and slopes, causing springs and swamps to occur. Then by attacking the water at its source, finding the main springs and diverting the water by one means or another, he was able to drain large areas of land by the use of relatively few drains. These were generally deep, open drains because no suitable drain pipes were then available, but the chief factors in his success were his careful study of the lower depths in the soil in the search for the water-bearing strata, and the judicious placing of his deep ditches in relation to these. In some cases he employed the method of boring with an augur through imperious layers to make the passage of water easy. These developments of drainage practice were so highly valued at the period that Parliament presented him with £1,000 and appointed John Johnson, of Edinburgh, to study his methods and write up an account of them. This system of drainage is equally applicable to-day to the conditions for which Elkington designed it as it was in the eighteenth century, with the advantage that in many cases pipe drains can take the place of the open ditch.

The next development of drainage practice occurred during the early-middle part of the nineteenth century, when a fierce controversy occurred between William Smith, a Perthshire farmer, and his partisans and Josiah Parkes, the consulting engineer to the Royal Agricultural Society, and others, upon two systems of underground drainage. Smith advocated his "frequent drain system" at distances apart varying between 10 and 24 ft. at a depth never

exceeding 30 in., the drains being constructed of stones, and not of *tiles, which by this time were available.* Parkes advocated drains *of a minimum depth of 4 ft., with the idea of tapping "subterranean water" as well as surface water, placed at much less frequent intervals from 20 to 50 ft. apart, and constructed of hollow pipes of only 1-in. bore. The wider intervals between drains and the narrow bore* rendered the cost cheap (not exceeding £3 per acre in those days). The pages of the early numbers of the Royal Agricultural Society's Journal and the Transactions of the Highland Society bear eloquent testimony to the keenness and bitterness of the controversy. We now know that both parties were partly right and partly wrong. Smith was right in advocating frequent shallow drains in heavy impervious soil, waterlogged because there was little or no natural drainage through it ; frequent drains are not necessary in porous soil where wider, deep drains are advantageous because water can pass readily to them in a lateral direction. Parkes was right in advocating pipe drains, though 1 in. in diameter is much too narrow. He was right in advocating deep drains in porous soil, provided the outlets to these could be permanently guaranteed. [It is, unfortunately, the fact that many otherwise satisfactory deep-drainage systems have been completely immobilised by the silting up of the ditches into which they were led.] But excessively deep drains in many clay soils have been rendered valueless because, with the passage of time, the soil has compacted, and plough pans have been formed, so that porosity has been destroyed and water fails to reach the pipes quickly enough to prevent water-logging. Much advantage, however, accrued from this fierce controversy because public attention was rivetted on the subject, and the Land Drainage Act of 1846 set aside £3,000,000, a very large sum in those days, for the purpose of loans to assist landowners to improve their lands by drainage. These and other similar loans fostered immense activity in land drainage, resulting in the efficient drainage of very large areas of cultivated land in Britain during the succeeding thirty years.

Bailey Denton, who was engineer to the General Land Drainage Company, advocated a middle course between the tenets of Smith and Parkes. He advocated deep drains, provided they were sufficiently close together to remove stagnant water and allow air to take its place, and speculated upon the better textural conditions produced by draining, which, he contended, converted non-permeable into permeable soils, by causing soil cleavages. These in turn became water channels for the next season's rain. But he also strongly advocated the subsequent deeper cultivation of drained clay land in order to prevent the formation of a plough-pan and to facilitate the downward passage of water from the surface to the drains.

Many of the drainage works, executed in the middle of the nineteenth century, in cases where the outfalls have been properly tended, are functioning perfectly to-day and indeed not a few

which had ceased to operate when the ditches were allowed to silt up, have been found to be in perfect order when these have been cleaned out.

During this period of intense drainage activity, attempts were made with mole plough drainage. In the first place horses were used as the source of haulage power. Direct haulage, even with six or eight horses, was unsuccessful, and when used in association with windlasses the work was very slow. The method, however, proved very suitable for use with steam ploughing engines, under suitable conditions, because of the low cost of operating. More recently, since the development of motor tractors, these have given some measure of success when hauled by the more powerful types.

King, the soil physicist of the United States, follows Bailey Denton in his advocacy of deep drains on all soils. He also advises the use of large drains, not less than 3-in. bore, because these are less likely to be blocked by silting or otherwise to get out of repair. He stresses the importance of aerated soil, following drainage, for root growth, and explains that crops feel the drought much less on drained soil, both because of the deeper range of roots and because drained soil, with its better texture, holds more water for the service of plant roots. King, developing the idea of the cracking of the soil following drainage and the deeper growth of the roots into these soil spaces, explains that the presence of these roots, both living and dead, introduce organic matter into these spaces which, in their turn, provide planes of partition for the future cracking of the soil and passage of water. He also explains that soil bacteria and other organisms, including worms, similarly penetrate these deeper cracks in the soil when lined with the root remains, and they in their turn help progressively to improve textural conditions. The benefits of drainage to the texture of the soil are thus cumulative.

The Need for Drainage.—In order to obtain a clear idea of the circumstances which give rise to the need for draining, it is necessary to consider the fate of rain falling upon a land surface which, in the first instance, is dry. The first rain which falls, provided the rain does not fall too rapidly, is absorbed by the soil in a manner similar to that by which water is absorbed by a sponge. The soil becomes moist and the water is held within it. At first there is no drainage of water through the soil because the water is held by capillarity on the surfaces of the soil particles, the soil spaces then being filled partly by air and partly by water. As more rain falls a state is reached when the soil can no longer hold all the water by capillarity, the excess of water then sinks downward, under the action of gravity, until it reaches an impervious or nearly impervious layer in the soil. Such layers may occur close to the surface or may not occur until a considerable depth is reached, but when reached the water begins to collect upon them as upon the bottom of a bowl and a water surface, called in the soil a "water-table," is formed. As more rain falls and more water drains

downward, the water-table rises, and in doing so forces upward and out of the soil all the air which previously occupied the soil spaces. Eventually the water-table reaches the surface, the soil is then saturated with water, and the land is said to be water-logged. If still more rain falls the water-table rises above the surface of the land and the water begins to run over the surface of the land down the slope of the hill until it reaches either some stream, by which it is eventually evacuated into the sea, or a cup-shaped depression in the land surface where a flooded area is produced.

If during the downward passage of rain-water through the soil to an impervious soil layer below, the water passes through a freely porous layer, then, when the water-table reaches this porous layer, another alternative may occur. Water can move not only vertically but also horizontally through porous layers in the soil. When the porous layer is continued horizontally or on a decline towards *the floor of some stream or river, the water may pass by natural drainage or seepage into these channels, or the drainage waters may be transported underground through such porous layers in a* horizontal direction until the limits of these porous layers are reached. In this case, if the pressure of gravity is sufficient, the water may be again forced upwards to the surface of the ground leading to the formation of springs. Such springs may run continuously or intermittently throughout the year and give rise to wet, marshy places on the lower slopes and bottoms of the valleys.

From the foregoing it will be seen land may be wet and need drainage, owing to water derived from three sources. Each of these will require separate treatment. Firstly, the surface flooding of land in which case rain-water " runs off " the surface to collect at some lower level. Secondly, the " water-logging " of land when rain falls upon impervious soil. Thirdly, underground water, transported through porous layers in the soil and causing marshy areas where the underground water rises to the surface as springs.

Flooding.—One case of flooded land has already been described. but it is important to recognize that other circumstances may give rise to this : thus, rain storms in tropical and semi-tropical countries, and thunderstorms generally, shed rain so rapidly that even porous soils are unable to absorb the water sufficiently fast, with the result that much water is run off the land to produce flooding at a lower level, or when much water has to be evacuated through narrow, winding streams and rivers in a flat area they overflow their banks and flooding is produced. This type of flooding is accentuated in urban areas by the rapid run-off and drainage of rain-water from the roofs of houses and tar-paved streets, and in agricultural areas by efficient drainage and ditching of the land.

Flooding, by whatever cause produced, requires the same general treatment—the rapid evacuation of relatively large volumes of water. No underground system of drainage with restricted channels can successfully accomplish this. The construction of wide, open surface channels, the effective capacity of which increases as the

flood rises, provides the correct solution to these conditions. These open or surface systems may be applied to relatively small areas, but they are frequently employed for the drainage of large areas, as, for example, the Fenlands of Cambridgeshire and Norfolk, in which the work falls within the province of the engineer rather than the agriculturist.

The second case in which the land needs draining owing to rain falling upon impervious soil may, under primitive conditions, also be dealt with by surface drains. These are, however, not generally suitable for cultivated land, whether pasture or arable, because the *open drains interfere with the ordinary acts of tillage and husbandry.* They are best dealt with by some system of underground drainage by which, as soon as the water-table rises above the level of the drains, water passes into the drains and is evacuated. In this way the water-table is prevented from rising in rainy weather and, consequently, some air is always retained within the soil. This system of draining is sometimes described by the name of "thorough" drainage, sometimes parallel-drainage.

The third case, in which the wetness is caused by underground or spring water, is that against which Elkington devised his system of draining. It is sometimes called deep-draining or spring-tapping, and consists of locating the main springs and tapping them by means of a few deep drains so placed that the water is prevented from reaching the springs and so from flooding the land.

Surface-draining.—Surface-draining has many applications to farming conditions, and one of its chief recommendations is the simplicity both of its execution and maintenance. The open character of the drains, in comparison with other systems, makes any fault immediately obvious and capable of repair, and large volumes of water may be removed at little cost, provided attention is given to the choice of the line for the drain or ditch and to the occasional clearing out of its channel.

The system is perhaps illustrated in its simplest form by the ridge and furrow system of ploughing into "high-back" lands, so characteristic a feature of heavy-land ploughing in this country under the Manorial system, is a method of ploughing still practised in a modified manner in the stetch-ploughing in Essex. The essential features of this system, still to be observed in many pastures formerly cultivated in this way, are the continuous "gathering" of the plough furrows to form the high centres of the "lands" and consequently the deep furrows between them, and since these furrows were always designed to run up and down the slope of the field, any excess of rain-water drained from the high back lands to the furrows and then down the furrows into the ditches at the bottom of the fields.

This method is illustrated at the present day by the gathering of ploughed fields into ridge and furrow when ploughed by the common plough, and again by the ploughing out of water furrows after land has been ploughed or cropped in autumn. These furrows are

ploughed along the lowest slopes so that water may drain out of the hollows.

Surface-draining is again generally employed in plantations and woodlands, where the tree roots would interfere with pipe drains. It is also used on hill pastures when these need draining. In this case the drains are generally cut transversely across the slope of the hill and led into mains placed in the lowest slopes.

These drains are generally not more than 12 in. to 18 in. deep, and cut at frequent intervals in localities where rainfall is heavy.

As previously mentioned, this system of drainage is always practised on land liable to flood by the side of streams and rivers. In this case the drains may be wider and deeper than in the cases previously mentioned, because of the greater volume of water to be evacuated, and the main drain may be led to empty back into the river at a point lower down the valley, frequently below a mill-dam, where this accentuates the flooding above.

One other case of surface-draining frequently requiring attention on the farm, although often neglected, is the grading and provision of channels by which rain-water may drain away from the roads and yards about the buildings and the farm. Too frequently such roadways become impassable quagmires in rainy weather during winter. If a little attention is given during dry weather to the grading and filling up the hollows in the roadway and the provision of gutters for the run-off of the water, these conditions could be largely prevented.

Under-drainage.—It has already been explained that this system of draining is adopted in cases where natural drainage is unable to remove the excess of rainfall quickly enough to prevent water-logging of the land, and is specially necessary, therefore, in the case of impervious and heavy soils. In districts where rainfall is heavy the need of such under-drainage is naturally greater than those in which rainfall is light. Thus, some soils of a medium character may drain themselves naturally in districts of low rainfall, whilst similar soils in districts of high rainfall become badly water-logged and therefore need under-drainage.

The most important part of any draining scheme is the preparation of a drainage plan to guide the actual work. So often a farmer in executing his first drainage work finds a wet place in his field and digs a single drain to overcome this trouble. Later other wet places develop and further independent drains are made. Finally, the area is covered with a complicated and therefore expensive muddle of drains, and is even then not properly drained.

There are some few simple cases where the area is small and the slope is obvious and uniform over the area in which the plan can be easily thought out, but in the general case, and especially where considerable areas are involved, the first procedure should be to take the levels systematically over the area at intervals of a rod apart, or more frequently where obvious irregularities in level occur. These levels should then be plotted on squared paper and the

contours drawn. Then the plan of the draining should be thought out.

With the levels and contours thus plotted, and with a knowledge of the general-lay-out of the land, the points for the outfalls should first be selected. These should be placed at the lowest available points emptying into a ditch or stream, so as to give the greatest fall for the drains. It is desirable to reduce the number of outfalls to a minimum because these are sources of weakness in a drainage system unless substantially constructed, and when substantially constructed they are expensive. The outfalls should, if possible, avoid proximity to trees since the roots of these are liable to disturb them or drains leading to them.

The main drains, leading from the minors to the outfall, should, in general, be placed along the line of the lowest fall, leaving the minors to be placed on the lines of the steeper falls. This provides for a more uniform rate of flow of water through mains and minors, because the greater volume of water collected in the main drains is subject to less friction in its passage through the pipes. The minor drains should be planned to run down or across the steeper slopes. They should in the general case be parallel to each other, so that the surface may be uniformly drained at least expense.

Depth of Drains.—In the first place, drains should be placed at such a depth that there is no fear of disturbance by agencies above ground. They must be well below the depth of the deepest cultivation by plough or subsoiler. There must be no danger of disturbance by the passage of horses or other animals, by tractors' wheels or farm carts, and especially, where such are used by the wheels of steam engines. They should also be sufficiently deep in land which is subject to serious cracking in summer to avoid displacement from this cause. The next point to consider is that the deeper the drains are placed, the lower will the water-table be kept, the deeper will the air penetrate and the deeper will be the area through which plant roots may grow in search of food and water. On the other hand, if drains are very deeply placed in heavy impervious land, the rate of passage of water into them, owing to the gradual compacting of the soil, may, after a few years, be so slow that water-logged conditions may again be produced.

In porous soil drains may with advantage be more deeply placed, because in such soil water penetrates easily and quickly to all depths, because digging is easier and because with deep drains in such soil fewer are required and they may also be placed at wider distances. In light, open soils drains should generally be placed 3 ft. to 4 ft. deep. In very heavy, impervious soils, the depth to the floor of the drain should preferably be 30 in. and not less than 24 in. When drains have to be placed in peat soils it is desirable, when possible, to dig the drains below the peat so that the tiles may rest upon the solid soil beneath.

Distance Between Drains.—The distance between drains depends in part upon the depth at which they are laid, as explained

above, in the case of porous soil. The depth in impervious soils, however, does not generally affect the distance apart since water can only pass very slowly in a lateral direction through such soils when the subsoil is compacted. The distance apart may also be governed by the amount of rainfall. When this is high the drains should be closer. The chief factor, however, in deciding the distance apart is the texture of the soil. When this is porous and the drains deep, they may be 60 ft. or even 90 ft. apart, when the soil is impervious they require to be no more than 18 ft. to 24 ft. apart. In cases where fields have previously been ploughed into ridge and furrow, and being now pasture, still retain this conformation, excess water will naturally run over the surface into the furrows, and in these cases drains may advantageously be placed in each hollow irrespective of the distance apart.

Gradient or Fall.—Water flows through drains owing to the action of gravity. The steeper the fall of the drain the more rapidly will drainage water pass through it. It is true that water will pass through drains if placed perfectly level, owing to the banking up of the water at the beginning of the drain, but this condition is undesirable because the passage of water is so slow that, if silt finds its way into the drain between the junction of the pipes, the flow of water is too slow to evacuate it. On the other hand, drains should not be given too steep a fall on hilly land lest the water tends to wash too rapidly through and by the side of the pipes. In doing this soil may be removed from below the pipes, which consequently settle. Too steep a fall may be obviated by planning the drains to run across the slope of the land instead of directly down it, and, in fact, such drains across a steep slope will collect and drain the water better than drains directly up and down the slope.

Not only is a fall necessary for the drains, but it is also desirable that the drainage water should pass through the drain at a uniform or increasing speed. The drainage water carries some silt with it which will have worked in between the edges of the pipes. If the flow of water is checked at any point some of the silt will settle out and tend to block the pipes. The flow of water in a drain in which the fall is uniform increases towards its outfall when the volume of water increases, and especially when a succession of minor drains empty their contents into the main drains. The reason for the increase of the rate of flow is that the friction of the pipes against the flow of water is proportional to the surface of the pipes in contact with the water. When the quantity of water in the pipes is small the area producing friction is large compared with the volume of water passing, and when the quantity of water passing through the pipes is large the area is relatively small compared with the volume of water. For this reason the fall necessary in the main drains to secure adequate scouring of the silt is less than that required in the minor drains. The optimum fall in the minor drains may vary between 1 in 50 to 1 in 200, and drains will function perfectly at gradients both much steeper and much flatter than these provided

the tiles are well and truly laid. For mains the fall, as a general rule, need be no more than half that in the minors.

Execution.—Just as in planning, so in execution, the work must start at the outfall. The exact point of the outfall must be selected with great care, so as to give a free outlet to the water. As a general rule, the outlet should be not less than 4 to 6 in. above the general level of the water in the stream or ditch, and should point slightly downstream. If the outlet is below the water level no real advantage is gained in fall, and the flow of water through the full pipe is likely to be so slow that silt is deposited. On the other hand, no serious harm will result if the outfalls are occasionally covered by flood water. Outfalls must be so placed and constructed as to resist the underwash of the stream and also the outward thrust of the bank in which they are constructed, as this expands and shrinks under the action of frost and thaw on the one hand and drying and moistening on the other. High bricked outfalls, extending above the surface of the land, may be pushed over by such a thrust in the course of a few years. Outfalls should also be provided with some form of flap or grating to prevent the entry of vermin.

Types of Outfall.—Under primitive conditions the outfall may consist merely of one of the pipes used in the main, which may be held in position by a piece of wire running back to the third or fourth pipe. Such an outfall is sure to become defective in the course of years, because, as the earth in the bank crumbles, the pipe becomes loose and falls into the stream. A more durable outfall should, therefore, be constructed. A more durable and inexpensive outfall can be constructed by using a long iron pipe, 6 to 8 ft. in length, for the outfall. Second-hand gas or water pipes are suitable for this purpose. If these are placed with the mouth projecting 6 in. into the ditch and the remainder placed in the firm ground of the bank, they are immune from any underwash of the stream as well as from any thrust from the bank. They are unlikely to be disturbed and can be easily found at any time.

A more expensive and perhaps more seemly type of outfall may be made in masonry with either concrete or brick and mortar. Where such outfalls are constructed special attention must be given to the foundations for the purpose of resisting the underwash of the stream and the thrust of the bank. They must be placed on a broad base and kept as low as possible. The ordinary drain pipes may be imbedded in the masonry or their place may be taken by special iron pipes. The face of the outfall through which the drain pipes project should be withdrawn slightly from the bank and not project too far into the stream.

In digging the main and minor drains the trenches should be no wider at the top than is required for the men to work, and at the bottom should be no wider than the diameter of the pipes, so that when these are placed the walls of the trench keep the pipes firmly in their place. Care must be taken not to disturb the floor of the

drain below the depth required to place the pipes, because if this is disturbed it is difficult afterwards to secure a firm bed for them. *The final levelling of the floor of the drain is made by a specially-shaped scoop,* and this part of the work requires to be done with extreme accuracy. Any inaccuracy in the fall of the floor will be reflected in the drain itself and will interfere with the regular flow of the drainage water—perhaps causing silting. In former days skilled drainers became so expert in " bottoming " the drains that they required no assistance beyond the help of a little water in the trench for testing the fall in the drain as the floor was being scooped out. Such skill is rarely attained at the present time, and the fall of the floor should frequently be tested by means of the boring rod or grade stick placed in the floor of the drain, sighting the top of this with the cross pieces set up at each of the grade stakes. These cross pieces are set up at the same height above the floor of the proposed drain as is the length of the rod or grade stick. An alternative method consists of stretching a line or wire 5 ft. above the *floor of the proposed drain, as shown in (Fig. 28), and testing the depth by means of an inverted L of the same length.*

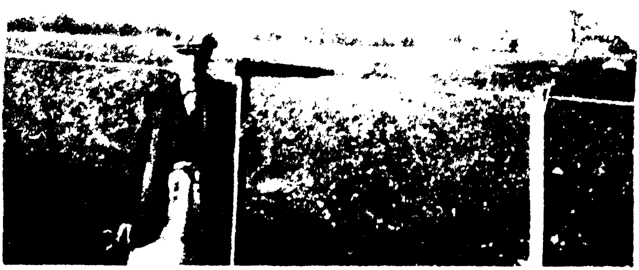


FIG. 28. TESTING THE FALL OF THE FLOOR OF A DRAIN.

Care must be exercised in making the junctions where the minor drains empty into the mains. If these are badly constructed earth may be washed into the drain through the faulty parts. Important junctions between two mains may best be made by the use of Y-shaped pipes or by the use of simple bricked catch pits, and these are specially useful if silting is likely to occur owing to any change in the rate of flow. When the junctions are made between minors and mains these need not be so elaborate. A hole is cut into one of the main tiles by means of a sharp tile-pick, or tiles with such holes may be specially made. The end of the smaller minor drain pipe is then chipped by a wrench-hammer or other implement, so that it fits accurately above this hole and delivers its water downwards

into the main. After the junction pipes have been carefully placed the junction should be covered over with broken tile or may be cemented over to prevent soil working into the drain.

When extensive draining operations are carried out, and especially if many deep mains have to be constructed, mechanical digging machines may be employed. These commonly consist of a large revolving wheel, fitted with digging shoes, mounted upon a framework and transported on caterpillar wheels. Such diggers are capable of excavating a draining trench to a grade as they move forward along the line of the drain.

Other forms of mechanical diggers of smaller types are being developed, but require to pass over the line of the drain several times to reach the required depth. Stones and boulders may be serious obstacles to their use.

Mole Drains.—At the present time the cost of under-draining with tile drains is so high and the value of farm crops so low that such under-draining is rarely profitable, except when the land is to be used for the growing of fruit or other valuable crops. Under-draining by means of the mole plough is comparatively cheap, and its results may be very satisfactory upon land which is suitable for this type of draining.

In mole-draining no tiles are used in the minor drains, which are formed by the haulage of a bluntly-pointed bar of iron called the "mole" through the subsoil at the required depth. This mole, which varies from 2 in. to 4 in. in diameter, is generally fitted behind with a ball or "plug" of slightly greater diameter, which squeezes the clay outwards, leaving a cavity after it has passed, which subsequently forms the drain. In plastic clay soil the walls retain their shape under favourable circumstances for several years, but in friable soils the walls quickly crumble and the mole-drain becomes obliterated. Mole-draining, therefore, can only be practised with advantage on stiff, heavy soils, and is unsatisfactory in friable soil.

The mole plough is not able to accommodate itself to irregularities in the surface of the land. If it is hauled over an irregular surface the mole drain will show similar irregularities, and these will quickly become silted up where the hollows occur. Mole-plough draining is, therefore, only suited to land where the surface gives a regular fall, and it is desirable that the fall shall be considerable.

Another undesirable condition for mole-plough draining is the presence of large boulders or patches of porous sand or gravel. The former are liable to throw out or break the plough, and the latter results in the drainage water being led into the porous patches, where it is trapped, and produces wet patches in the field.

In the most primitive method of execution, the mole plough is started from the bank of a ditch, so that the mole drains evacuate directly into it. This practice is unsatisfactory for several reasons; the outfalls quickly become blocked; the ground by the side of the ditch is frequently rough and irregular, so that such outfalls are

often very faulty ; and when steam engines are used for subsequent cultivation of the field the mole-drains are liable to be squeezed in by the weight of their wheels. It is, therefore, desirable to dig and construct adequate tile drains to serve as mains into which the moles may empty. When steam engines are used for haulage these mains should preferably be constructed before the mole-draining is executed. The mains should be sufficiently frequent and of large diameter, because when mole drains are freshly made the water is very rapidly drained away by them. In some cases the mole drains are connected to the tile mains by the use of three or four small tiles after the " moling " is finished. In other cases the connection of the moles to the mains is accomplished by placing a porous layer, about 6 in. deep, above the mains when these are dug, and then drawing the mole-plough directly across it. The mole-drains empty their drainage water into the porous material, and the water passes easily into the mains. The layer may in some cases be formed of clinkers or ashes, and in other cases hawthorn branches and other brushwood is carefully laid above the pipes before the earth is filled in.

In the first practice of mole-draining, direct haulage by horses was used, but this proved, in general, unsuccessful because the power was not sufficient to haul the mole at an adequate depth. Better results were obtained when horse-power was applied through the use of a windlass, but this was very slow work. The most suitable form of power is the stationary steam engine operating a double rope passing round a windlass fixed to the mole-plough itself. This provides ample power for the haulage of the large mole-plough at any required depth and over surfaces of land in any condition of wetness or texture. In recent years successful mole-drainage has been accomplished by the more powerful types of tractor, especially when operated upon grassland when the conditions are not too wet. Such work must generally be done with a small mole and at a lesser depth than with the steam engine, but since tractors are now commonly available in all districts, and the cost is low, tractor mole-draining provides a useful method for temporary work.

The depth of mole-draining should vary according to the power available and the nature of the land. When steam engines are used with a 3-in. to 4-in. mole the depth may vary between 20 in. and 30 in. Tractors are rarely able to haul a mole greater than 2 in. in diameter, and the depth should be not less than 20 in., but it may have to be if the power of the tractor is inadequate. The distance between the drains needs to be less than with pipe drainage, because the draining is less efficient. The width should vary between 6 ft. and 12 ft. apart, according to circumstances.

Mole-draining may in some cases operate successfully for as long as 10 years, but in other cases will become faulty in a much shorter time. Much depends upon the care in execution, the provision of adequate main drains and the nature of the soil. Amongst the causes leading to the destruction of mole drains are the presence of

moles, which quickly fill in the drains, and the deep cracking of the fields during very severe droughts.

Deep Draining or Spring Tapping.—Water passes easily through sand, gravel or other porous layers in the soil. These layers, therefore, tend to become water-bearing. It is through these layers that water finds its way to wells or to the floors and sides of streams and rivers, but when the placing of these layers is such that no free outlet is available, the water is held up, and as more water finds access to the layer the water-table rises. The water in the lower levels is subjected to considerable pressure, and it may be that springs are formed on the lower slopes of the valleys. These springs give rise to wet, marshy places wherever the spring water runs over the surface of the land on its way to the river or stream in the bottom of the valley. It was for conditions such as these that Elkington developed his system of spring-tapping, which was extensively practised in the eighteenth century, and much of the good work is still functioning though it is commonly not recognized as such. If, however, the ditches in the lower levels of many of our river valleys are carefully examined it will be found that springs are pouring water into them or that water is seeping into them from porous layers in their banks. These ditches, which now often form the boundaries of the fields, were originally dug for drainage purposes, and were they to be again filled in and no outlet given to the spring-water it would be found that the land for some distance below and above the ditch would revert to the marshy conditions which prevailed before the ditch was dug.

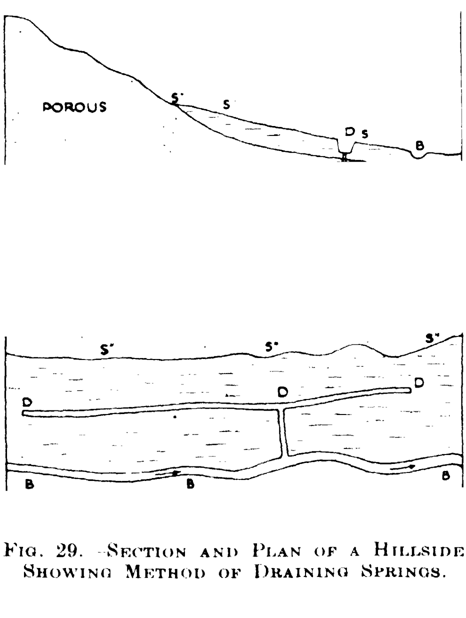


FIG. 29.—SECTION AND PLAN OF A HILLSIDE SHOWING METHOD OF DRAINING SPRINGS.

The diagrammatic section and plan of a wet, springy hillside will best explain one simple application of the method. H (Fig. 29) represents the line of crest of a hill, the top of which is composed of porous soil. When rain falls the water sinks into and through the soil until it reaches the clay below, where it is held up. As more rain falls the water-table begins to rise and springs develop at S, causing marshy conditions between this and B, which represents a brook in the bottom of the valley. During periods of heavy rain the water-table rises still higher till springs begin to develop in succession at S′ and S″, and the marshy conditions extend higher up the hillside. The springs at S′ and S″ are intermittent and stop running in periods of dry weather, when the water-table falls below them. Such springs were termed "false" springs by Elkington. The lowest springs, represented by S, run continuously, and were called "true" springs. Elkington found that if shallow drains D were dug at any point on the marshy slope they would collect a certain amount of water, but that if they were not deep enough to reach the porous layer little real good resulted. If, on the other hand, the ditch was dug deeply to reach the porous layer, or if occasional holes A were made with an augur through the floor of the drain to the porous layer below, then water gushed upwards into the drain, which evacuated large volumes of water and quickly drained the marshy places. The line of drain D D D shows how a single deep drain, placed above the line of the "true" springs tapping the porous layer, might drain a relatively large area on the sloping sides of a valley.

The diagrammatic presentation makes the execution appear to be simple. This, in practice, is far from being the case until a careful exploration of the subsoil, by means of inspection holes, has been made. The aim of the drainer must be to attempt to mark down the line of the "true" springs and then to tap these by means of deep, well-planned ditches or drains. If drain pipes are used to convey such spring water it is important to use tiles large enough to convey the relatively large amounts of water that will have to be dealt with. Such drains, carrying spring water, will run during spring and summer as well as during the dormant winter.

These drains are, therefore, likely to be blocked by deep-rooted crops such as sugar beet or mangolds or weeds, and especially by trees such as willows, the roots of which may travel along the pipe for 40 yards or more. Drains used for the under-drainage of rain water only carry little or no water during the period of active root-growth of plants, and, consequently, there is no inducement for such roots to grow into them, but drains carrying spring-water during summer, and especially during periods of drought, are very liable to such blockage. For this reason open drains are generally adopted for this system of drainage.

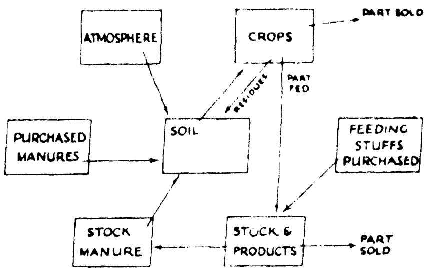
The system of deep-drainage has been represented by one case in its simplest form. It will readily be seen that many different and more complicated conditions may arise in practice and will require different treatment in detail.

CHAPTER V.

MANURES AND MANURING.

Effects of Farming.—In the section dealing with soils, the meaning of the term fertility, as well as the various properties of natural soils and the constituents which contribute to it, were considered. It is the purpose of this section to consider what effect the growing of crops or husbandry generally can have upon fertility, what practices may lower it, and by what agencies it can be maintained or augmented. It has been shown, in the main, to depend partly on the physical texture or tilth, partly on moisture conditions, partly on bacterial activity, and partly on chemical composition. Man attempts to influence these various factors by suitable tillages, rotations of crops, and the addition of a number of substances, which will be considered in detail. Some of these are added simply as plant nutrients while others fulfil a dual purpose of feeding the plant and of improving the physical condition of the soil, thus making it a more suitable medium for crop growth. Leaving aside for the moment the question of tilth, and confining attention to plant nutrients, it is a useful starting point from which to consider manuring, if the farm is viewed as a unit containing a limited amount of organic matter, nitrogen, phosphoric acid, potash and lime, and, in addition, a number of other substances of which the store in the soil is found ample except in a few unusual circumstances. Before the farm is established, vegetation of sorts occupies the land. This is supplied with food from the soil and the atmosphere, and on its dying upon the ground it adds to the stock of humus and nitrogen, and returns the mineral matter which has been drawn from the soil. By this process the soil has gradually arrived at a certain level of fertility. If now man takes possession and grows crops to sell away, he at once disturbs the balance of this system, and very rapidly lowers the fertility of the soil by the actual removal, particularly of the constituents named, in so far as they are contained in the products removed. This loss may not be appreciable when considered in relation to the total reserves present in any soil, but it must be remembered that it falls primarily on the available portion of the total, and so the soil becomes unable, in many respects, to provide anything like the amounts of some of the individual constituents necessary to keep up a high level of production. If the crops are used solely for the feeding of stock, or animal products for sale away, the inroads on fertility are less serious, because a good deal of the more valuable constituents is returned to the soil in the animal's excreta, and a noticeable feature of this type of unit is the concentration of fertility in certain parts of the farm, for example, round the farmstead and in the better pastures. Nevertheless, a certain amount of loss takes place. Pursuing this line of thought, a compensating effect is now encountered. Food, especially of the more concentrated kind, may be bought in for the stock, and a good proportion of its nitrogen

phosphates and potash remains on the farm, thus augmenting the natural reserves. This is entirely to the good, so long as it happens in respect of all the more important constituents and does not result in any one of them becoming markedly deficient. There is a last feature of a farming unit to be considered, and that is the deliberate importation of fertilizing substances from extraneous sources. The main lines of movement of nutrient materials are shown in the diagram :—



From this it will be seen that a certain amount of nutrient material is constantly being removed from the farm in the form of crops or animal produce, a certain amount is circulating—from the soil, through the crops, stock and farmyard manure, back to the soil, and a certain amount is obtained from the atmosphere, *i.e.*, nitrogen and carbon, or bought in as feeding stuffs and manures. Thus it will be realized that it is possible to balance gains and losses by adjusting the farming system to the inherent fertility of the soil, or to raise the level of fertility of the soil and increase its production or turnover. It is equally possible also, by specializing in one direction, to impoverish the farm in one or two main constituents unless measures are taken to replenish them from outside sources.

Many different systems of farming are practised or can be designed to make the most of the fertility of the soil, but the decisive factors in adopting any one are mainly economic, so that it is more useful to consider various prominent farming operations and the fertilizers procurable than to discuss the subject from the point of view of any particular system.

Fallowing.—The benefits of fallowing as a means of restoring the fertility of the soil were forced on the farming community at an early date. When agriculture consisted mostly of corn growing and sparse grazing, man soon found that he inevitably exhausted the soil to a marked extent and was forced to adopt a system by which he rested his land at regular intervals. He next discovered that it was helpful, not simply to leave the soil to its own efforts at recuperation, but to assist the process by tillages during the resting period. Thus the systematic fallowing of land became an established practice and remains to this day. The explanation of the benefits produced is not even now fully understood, but it is known

to a certain extent. Some of the more obvious beneficial effects of the fallow are the killing of all kinds of weeds by the actual drying out of the soil, the improvement of texture by alternate drying and wetting, coupled with effects due to temperature changes, and the accumulation of nitrates through the work of nitrifying bacteria in the absence of a growing crop. It would appear, however, that there are benefits beyond these. It may be that the drying or heating effects on the colloidal coverings of the soil particles are such that on re-wetting, a larger amount of the phosphate and potash in the soil comes into solution, or at all events is rendered more accessible to the general influences which render it suitable for absorption by the plant roots.

Green Manuring.—Occasions arise in farming practice when it is preferable, instead of leaving ground unoccupied for an interval, to grow a crop with the express purpose of ploughing it in later. This process is known as green manuring and has undoubted advantages in some circumstances. Its successful employment depends chiefly on rapid seeding and growth, and in this respect the use of a tractor is often the decisive factor. In the event of it being desired to follow up one crop with a green manure crop in the same year, it is essential to get the latter in quickly before the bare compacted surface left by its predecessor becomes totally dried out, a condition which follows rapidly, in dry weather, on the removal of the covering crop. Green manuring is also useful as a means of conserving the nitrates accumulated during any fallow period, if a rotation crop is not following at once, to utilize them before the winter rains, and also as a means of adding to the store of organic matter in the soil. Various crops are employed, such as mustard on chalk soils, lupines on light sandy soils, and tares on heavy soils. The process is not always successful, and its value appears to be affected by much the same factors as those affecting farmyard manure. The failures occur on light sandy soils in the drier parts of the country and appear to be due to much more rapid decomposition of the organic matter and to the utilization of the nitrates in the soil by the bacteria bringing this about, so that so far as the next surface crop is concerned, the soil is rendered slightly less fertile. A similar effect may sometimes be encountered where straw is ploughed in immediately before a corn crop, and can be attributed to the same cause. The operation of the factors which make green manuring successful are much the same as those concerned with alternate husbandry, by means of which the land, when under a three or four years' ley, is considerably enriched in humus and nitrogen, whilst at the same time producing crops of hay, so that when the ley is broken up, the benefits are particularly apparent both in the ease with which a tilth is established and in the enhanced yields of the arable crops which follow.

Farmyard Manure.—In spite of the growth of the fertilizer industry, farmyard manure is the mainstay of British crop production and is worth all the care and attention which can be bestowed upon

it. It is the product of the intermingling of the fæces and urine of various farm animals with straw or some other form of litter. There is obviously great variation possible in its composition, but in spite of this the properties of the final product are strikingly constant. A consideration of some of the factors involved is of use in explaining the points of practical management of this commodity. Of the material fed to the animals the chief fertilizing value obviously lies in its content of nitrogen, phosphoric acid and potash. The following approximate figures show the varying extent of these constituents :

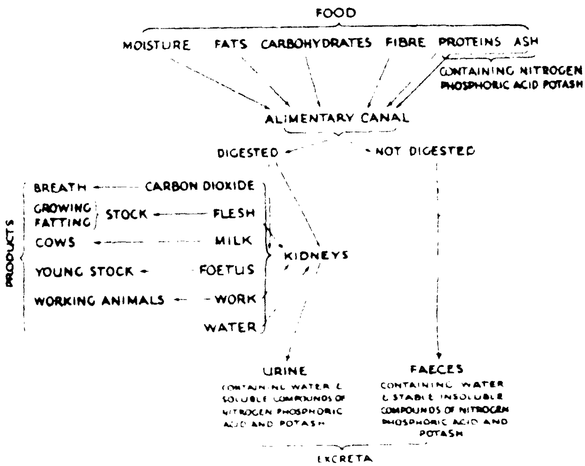
	Nitrogen.	Phosphoric Acid.	Potash.
Decorticated cotton cake... ...	7	3	2
Undecorticated cotton cake ...	3	2·5	1·6
Beans	4	1	1·3
Oats	2	·6	·5
Meadow hay	1·5	·4	1·6
Oat straw	·5	·3	1
Swedes	·25	·1	·2

Different foodstuffs are of varying digestibility ; some of their constituents, both from the point of view of organic compounds and of manurial value, pass through the animal unchanged, and it seems reasonable to assume that what proves indigestible to the animal is not likely to be " available " to the plant until it has been broken down by some suitable agency. Of the portion of the food digested, some is used to provide energy for the animal and is in effect burnt up, some is stored as fat, and some is used to replace body tissues. The digestible fats and carbohydrates contain nothing of manurial value, and that portion of them which is not converted into animal fat is got rid of entirely as water and carbon dioxide. The undigested portions are voided as fæces. The proteins are the nitrogen-bearing constituents, and of these a good deal may be used in producing growth (flesh), milk or young, thus ultimately leaving the farm. But a certain amount of the protein is used *to replace similar compounds consumed by wear and tear* in the animal's body, and this is the portion whose nitrogen appears in the urine as comparatively simple compounds, such as urea, which has been collected in a soluble form by the kidneys and thence *passed out dissolved in water. The ash constituents, phosphoric* acid and potash, also appear partly in the urine. The main lines of these various processes are set out graphically on page 107. Examination of this diagram will show that working horses, fattening stock and store animals will not retain much of the manurial constituents of their food, while growing stock, pregnant animals and animals in milk will take a good deal, especially of the nitrogen and phosphoric acid.

The litter also has a definite content of manurial constituents, as shown in the table above (*v.* oat straw). Its first function is to absorb the urine, although conditions in which it accomplishes this to any considerable extent are rare. Straw will absorb two or

three times its own weight of water, while peat moss or similar material can assimilate as much as ten times its own weight of water and in addition can absorb considerable amounts of ammonia gas, a compound which is formed in considerable quantities on the decomposition of urine. Its advantage over straw in this respect, however, is offset by its stability and its resistance to decay, so that it does not rot down in the same desirable manner as farmyard manure.

Thus, at the time of production, farmyard manure consists of a crude mixture of straw, fæces and urine, commonly termed "long dung," but this at once begins to undergo various changes which result in it ultimately producing a very uniform material in which many of the original differences of composition, due to the



type of animal, richness of food, amount and type of litter have been considerably mitigated if not obliterated. To begin with, the bulk of the manurial constituents are in the urine, so that to the extent that this is allowed to drain away, they become a total loss. Liquid manure tanks and suitable drainage systems avoid this loss where they exist, but with the increased use of water for washing purposes in cowsheds the difficulty of using them to the best advantage has been aggravated. The soluble compound of nitrogen, urea, is very quickly converted by bacteria into ammonia. Its presence, particularly in stables, is usually obvious. It appears as a gas whenever the litter or floor dries out, but so long as conditions are moist it remains in solution. This change of urea into ammonium compounds is only one of many which are brought about by bacteria in the manure heap. Each change comes into prominence as the conditions of moisture and aeration in the heap become suitable. The most important are as follows :—

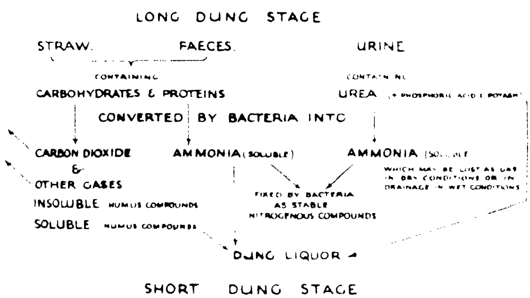
(1) The conversion of urea into ammonium compounds.

(2) The fermentation of the carbohydrates of the litter and fæces with the production of heat, various gases, such as carbon dioxide, methane and hydrogen, and a decayed mass of organic matter richer in carbon and darker in colour than the original straw.

(3) The breaking down of the proteins of the litter and fæces into simpler compounds of nitrogen such as ammonia.

(4) The assimilation and fixing of nitrogen as protein in the bacteria.

These changes become manifest in the gradual disappearance of any recognizable structure, the whole heap tending to become uniform in texture and colour. The raw soluble compounds of nitrogen gradually disappear, and drainage from the heap takes on a dark brown or black colour. This is dung liquor, and its appearance is due to the presence of soluble compounds of ammonia and organic matter. When all these changes are well advanced, the heap is in the condition known as "short dung." There is inevitably a great amount of wasting in the heap, both as regards total weight and amount of fertilizing constituents. Observations indicate that some 15 per cent. of the nitrogen is lost in the first few days, and that this loss steadily increases to as much as 40 or 50 per cent. as storage continues. Yet, in spite of this, the final product as a rule is richer in nitrogen than the original components owing to the comparatively greater loss which falls on the non-nitrogenous constituents. In the diagram below the main changes in a manure heap are set out :—



Reference may be made, in addition, to one or two specific points in the making of farmyard manure. The initial losses of nitrogen may be minimized by allowing manure to accumulate beneath the animals, a practice carried out with success in the case of fattening animals in suitable concrete-lined boxes. The daily removal of manure leads to the heaviest initial losses, especially if it is thrown out into a yard in casual fashion. Losses in yards and heaps may be cut down by collecting the manure in a well compacted heap on a concave surface kept free from surface and roof drainage.

Enough has been said to describe the nature of the fertilizing constituents in farmyard manure, both in the long and short dung stage. It should, however, be realized that although it is a general fertilizer, it is not well balanced. An average sample contains about ·7 per cent. nitrogen, ·25 per cent. phosphoric acid and ·5 per cent. potash, so that the amount of phosphoric acid is very low in comparison with the other constituents. If these figures are converted into their equivalents of the common fertilizers, a ton of dung will provide the same constituents as $\frac{3}{4}$ cwt. of sulphate of ammonia, $\frac{1}{3}$ cwt. of superphosphate and 1 cwt. of kainit. Expressed thus, the deficiency of phosphoric acid is better appreciated.

But the content of the three main plant nutrients in farmyard manure is not its only value ; indeed, its beneficial effects are probably due in a greater degree to other factors. There are three points with regard to the humified organic matter in it which must be borne in mind. Firstly, this constituent exerts a profound influence on the tilth of the soil, whether it be light or heavy. It opens up heavy soils and gives body to light soils. While it improves drainage and aeration in the former, it improves the water holding capacity of the latter. Secondly, its content of stable nitrogenous compounds makes an almost permanent addition to the fertility of the soil, which, by its continuous use, is considerably increased. Thirdly, it exerts some peculiar but markedly beneficial effect on young leys of leguminous crops such as clovers. Finally, considered as a whole, the use of farmyard manure is the best means of maintaining fertility, for it mitigates to a great extent the effects of seasonal variations in weather, and in any one year it gives the most equable effect.

It has been pointed out that any disturbance of the heap leads to renewed bacterial activity and further loss of manurial value. This point is of importance in applying the manure to the land, and recent experimental work has stressed the advantage which is gained by following up the carting on to the land by spreading and ploughing in with as little delay as possible. It is rarely the case that a farmer ever has as much dung as he would like to put on his land. With this difficulty in mind, and remembering the lasting effect which farmyard manure has, its deficiency in phosphoric acid and its cost of production, there is a strong case for the judicious use of purchased fertilizers to supplement the home product and to get from it its maximum effect in maintaining the productivity of the farm. The following figures indicate the possibilities in this direction :–

		£	s.	d.
20 loads of farmyard manure at 7s. 6d.		7	10	0
10 loads of farmyard manure at 7s. 6d.	=	3	15	0
1 cwt. sulphate of ammonia	=		6	0
3 cwt. superphosphate	=		9	0
$\frac{1}{2}$ cwt. muriate of potash	=		4	9
10 loads of farmyard manure + purchased supplement	=	£4	14	9

7s. 6d. is taken as the cost of farmyard manure in the yard. The additional expense of the application of the larger quantity has also to be taken into consideration.

Before leaving the subject of farmyard manure, some reference *must be made to recent work on the subject. The most interesting, without doubt, has been the elaboration of a process for the artificial production of manure from straw or other vegetable refuse,* which followed on discoveries made at Rothamsted on the nature of the changes proceeding in the manure heap. Briefly, it was found that two sets of organisms, working independently, brought about two main results, the one the rotting of the straw and the other the fixation of nitrogen. It was also found that the former needed a supply of readily available nitrogen compounds to enable it to go on. *By building up a heap of straw, layer by layer, each of which* was well watered and given a sprinkling of chalk, and by washing in some easily soluble nitrogenous fertilizer such as sulphate of ammonia, a complete rotting down of the heap to a product which was very like short dung, and which gives the same results in the field, was effected. The process has been further developed and is *now handled on a commercial scale by a non-profit-making syndicate known as Adco, Ltd.*

In the making of farmyard manure it would appear that the great importance of the urine lies in the fact that its content of soluble nitrogen compounds enables the straw-rotting organisms to do their work, a point which would seem to have a bearing on the quantities in which straw should be supplied as litter. To prescribe a definite figure, such as 1 ton of straw to every 100 lb. of digestible protein in the food supplied may be a counsel of perfection, but it is based on facts which are well worth attention in the making and management of farmyard manure. On the Continent, work has been done of recent years on the control of the process of making farmyard manure, and much controversy has arisen on the Edelmist Process. This aims at encouraging active aerobic fermentation in the heap during the first few days of its existence, so that a temperature of 60—70° C. is reached, after which the heap is compacted by pressure, protected from the weather and left undisturbed for four months. The advocates of this process claim that the manure is thus completely humified and that all weed seeds are killed.

Liquid Manure.—Reference has been made to the urine of farm animals and its composition and the loss involved in the absence of any liquid manure tank system. The profitable utilization of liquid manure, however, bristles with difficulties. The volume produced may be too large to store or even to handle, and whereas a tank needs to be emptied at regular intervals, the land is not always ready to receive its contents. It is most easily dealt with, therefore, on grass land, on which it can be applied at most times. It is impossible to give a composition analysis for it owing to the enormous variations of dilution to which it is subject.

Undiluted urine drainings, on the one hand, may be so concentrated as to be harmful to vegetation, while yard drainage during spells of wet weather, on the other hand, may be little more than polluted water. A common strength, however, is one at which 1,000 gallons will contain the equivalent of 1 cwt. sulphate of ammonia, ¼ cwt. of *superphosphate and ¼ cwt. of muriate of potash. It is in effect a* nitrogenous stimulant and encourages coarse rank growth. Accordingly, its best use is on meadows when yield rather than quality may be desirable.

Poultry Manure.—In these days, when poultry farming has come into its own as a specialized industry or as a branch of farming, the value of poultry manure is becoming more appreciated. It is estimated that 1,000 birds, normally housed, will produce 2 cwt. of droppings in a day. If half of this falls in the houses, it is obvious that a useful supply of manure will gradually accumulate. Its analysis varies between 1 and 4 per cent. nitrogen, 1 and 3 per cent. phosphoric acid and ·5 and 1·5 per cent. of potash, so that 7—8 cwt. of it should constitute an effective dressing per acre, although, like farmyard manure, it is comparatively deficient in phosphates. The value of the fertilizer will be increased if stored under a roof in airy conditions, and mixed with one-third to one-half of its own weight of dry earth as it accumulates. This improves the physical condition of the manure and lessens the loss of nitrogen as ammonia. Already processes have been elaborated for conserving, drying and grinding poultry manure.

Purchased Fertilizers.—In ordinary farming, the purchase of fertilizers consists of buying commodities containing one or more of the principal plant nutrients, namely, nitrogen, phosphoric acid, potash and lime. Each of these substances has its particular effects on plant growth, and as the form in which it is offered to the plant may also have specific effects, it will be profitable to consider individually the materials which are obtainable. Of these there is a wide choice available, and for each one there can be claimed special advantages in certain circumstances, so that a knowledge of the properties of the various kinds may enable the farmer to come to a decision as to which are most likely to serve him best for any particular purpose. It is useful, also, to bear in mind that some kinds are available only in comparatively limited quantities, a fact which has its effect on the price at which they can be bought. In the majority of cases a grower will use fertilizers to obtain their effect with fair celerity, but in some cases he may be content to get the effect less quickly while gradually building up the fertility of his soil. In the former case he is best served by a material which is in a form immediately assimilable by the plant, or readily and quickly converted by bacterial or other action to an available form. Then the more soluble it is in water and the more finely divided it is, the more thoroughly can it be disseminated through the soil and the quicker it will act. In the latter case, substances of a more durable nature are desirable, such as will release the desired constituent

slowly but evenly over a long period, so that regular additions continually increase the reserve in the soil, and hence the supply at any particular moment. Other points which are of practical importance are the keeping qualities of the manure, its concentration, the ease and comfort with which it can be handled, and the evenness with which it can be spread.

Nitrogenous Fertilizers.—The effects of nitrogen-containing manures upon plant growth are amongst the most spectacular which can be achieved by manuring, for they provide the food material which is especially responsible for growth, particularly of the foliage and stems. This is to be desired on occasion, but it may become a handicap if, for instance, the production of grain is the main object of the crop. Though yield increases are obtained in all parts of the plant, the excessive use of nitrogenous manure leads to the predominance in the yield of the normally less valuable parts of the crop, as, for instance, the proportion of straw in a grain crop, or of leafage in a root crop. Its use has a marked effect on the appearance of herbage, giving to it a luscious green appearance; indeed, the lack of it is often shown by a stunted growth, characterized by pale- or yellowish-green leaves. There are two things to beware of in the use of a quick-acting nitrogenous manure; they are its tendency to retard the ripening processes and its tendency to produce succulent and weakly growth. These effects become apparent more quickly when the soil is deficient in phosphates and potash. Weakly growth due to this cause has two drawbacks; it may be unable to support the weight of its own structure and so become laid, or it may fall victim to the attacks of fungoid pests.

Organic Refuses.—In dealing with the soil, reference was made to "the nitrogen cycle." If any individual fertilizer is considered in relation to its position in the cycle, its chief characteristics, and especially its availability or speed of action, can be more easily understood. The plant commonly absorbs its nitrogen in the form of nitrate, and all other forms must first of all be converted into it.

The important organic refuse manures are :—

(*a*) ANIMAL RESIDUES		
Shoddy	3–15	per cent. nitrogen.
Hoof and horn	13–14	,, ,,
Dried blood	6–14	,, ,,
Leather refuse	15	,, ,,
Fur, Hair, Skins, Feathers	8–12	,, ,,
Meat meal	6	,, ,,
(*b*) VEGETABLE RESIDUES		
Castor seed meal, Rape ,, ,, ...	5–8	,, ,,
Malt culms or dust	3–4	,, ,,

The animal residues originally contain large quantities of protein, and unless they become contaminated with dirt or are mixed with other substances during the processes which lead to their

production, they may contain up to 15 per cent. nitrogen. Their utility and value depend partly on their nitrogen content but more on their physical state. For instance, the barbs of a feather or finely-ground fragments of hoof and horn have an obvious advantage over pieces of shoe leather when considered as fertilizers. All these materials may be regarded as comparatively slow acting and useful for raising the fertility of the soil, *i.e.*, they have residual values. They are therefore in demand by intensive growers for use in market gardening, hop and fruit growing. This, coupled with the rather limited supply, probably explains the fact that they are usually the most highly-priced forms of nitrogen.

A glance at a price list or market report shows very great variations in the prices per ton of different fertilizers. Nitrogenous manures as a whole are the most, and phosphates usually the least, expensive. The Fertilizers and Feeding Stuffs Act ensures the description of most of these commodities in terms of the amount of the main fertilizing constituents which they contain, *e.g.*, nitrogen —N, "phosphoric acid"—P_2O_5, and "potash"—K_2O, expressed as percentages. One per cent. of a ton, or 22·4 lb., is usually taken as a convenient unit on which to compare prices; thus, 1 ton of sulphate of ammonia (20·5 per cent. nitrogen) contains 20·5 units of nitrogen, and 1 ton of nitro-chalk (15·5 per cent. nitrogen) contains 15·5 units of nitrogen. As the prices per ton of these two commodities are (Sept., 1931) £5 10s. and £7 9s. respectively, the cost per unit of nitrogen is 5s. 10d. in the former and 7s. 9d. in the latter. The system of unit prices provides a useful criterion of values, but to make it the final or sole test of worth is unsound for the reason that there are other differences of practical importance which may considerably modify comparative values assessed solely on unit price. In the case of the two materials cited above, for instance, the higher cost per unit of nitrogen in nitro-chalk may be offset by its special value as a top dressing on soils lacking a satisfactory reserve of chalk, or on crops whose root system is deep rather than shallow. Most fertilizers have their individual peculiarities which give them their highest value for some particular set of circumstances, and in these cases the unit price of their constituents loses its importance and may become, in fact, a minor consideration.

SHODDY is a bye-product of the woollen industry. Pure wool is wholly protein and contains 16 per cent. nitrogen, so that the fragments which are discarded in woollen manufacturing as shoddy will approach that figure. But in some processes the fabric manufactured contains an admixture of cotton, a substance which contains no nitrogen, so that it is possible to have almost any percentage of nitrogen in shoddy, according to the nature of the material being made up. For this reason shoddy receives special mention in the Fertilizers and Feeding Stuffs Act, which exempts it from the statutory declaration of its nitrogen content. Shoddy is, on the whole, a finely divided material, but it is of such a nature that it is bulky and not easy to spread in small quantities. It is highly

esteemed by intensive growers, who often apply it at the rate of a ton per acre.

HOOF AND HORN similarly contains a high proportion of protein and so of nitrogen. It is dried and ground so that an effective spread can be obtained with a few hundredweights to the acre.

DRIED BLOOD also is marketed in a very good physical condition. Its content of nitrogen varies as sometimes the drying process is helped by the addition of lime which, of course, has its own value but must inevitably reduce the percentage of nitrogen in the final product.

LEATHER REFUSE is occasionally available as a fertilizer, as are also fur, hair, skin, feathers and meat meal. All these commodities vary so much from one consignment to another that it is impossible to describe them precisely. They all have potential fertilizing value, but their value can only be computed with difficulty. Sometimes the material is of such a tough nature that it can be recognized in the soil for years; in this case it is obviously of poor value as a manure. It is necessary that it should be finely divided or that it should be chemically treated in order that it may easily undergo the changes by means of which its nitrogen content becomes available for plants.

The vegetable residues form a group by themselves. They are usually the result of processes which have extracted certain constituents of seeds for technical purposes, leaving a residue which for some reason or other is unsuitable for use as a foodstuff. It will thus be realized that they cannot as a rule be very rich in nitrogen. The average seed contains carbohydrates, fibre, ash, moisture, oil and protein. In the case of rape and castor seed the last two are the most abundant constituents. The oil is extracted for various purposes, leaving a residue in which the protein provides nitrogen to the extent of about 6 per cent. of the bulk. Small amounts of phosphoric acid and potash are also present.

All these organic manures have their chief value in their nitrogen content, this often being of a form which becomes available gradually. In some instances the conversion is so rapid that an immediate response is seen in the crop, and the manure is practically used up in one season. This is the case with dried blood and seed refuses. With others, such as shoddy, hoof and horn, fur, leather, etc., there are greater or less residual effects, so that their use results in an improvement in the fertility of the soil of a semi-permanent nature. This property is reflected in the practice of awarding compensation for their use on the termination of a tenancy. Voelcker and Hall, for instance, on the ground of experimental results at Rothamsted and Woburn, recommend that for shoddy, fur, hair, hoof and horn, half value should be allowed after one crop, one quarter after two crops, one eighth after three crops, and nothing after four crops.

Artificial Nitrogenous Fertilizers.—The fertilizing value of many of the organic refuses has been known for years, but in and since

the last century a number of simple chemical compounds have been discovered and developed as cheap and convenient forms of nitrogen. Of these, sulphate of ammonia, a bye-product from gas works, and the naturally occurring nitrate of soda of Chile were, for many years, the chief representatives, but at the present day they are equalled in importance by the many synthetic forms of nitrogen now manufactured, particularly sulphate of ammonia, nitrate of ammonia, nitrate of lime, cyanamide and muriate of ammonia. The world production of these nitrogen compounds is made up of roughly two-fifths sulphate of ammonia, of which more than a half is synthetic; one-quarter Chilean nitrate of soda, one-tenth cyanamide, one-eighteenth nitrate of lime, and one-sixth other synthetic forms. These approximate figures give some idea of the relative importance of the various commodities, though the proportions in which they are employed in various countries varies a good deal. The discovery of means by which the huge reserves of gaseous nitrogen in the atmosphere could be employed to produce solid compounds of this element was made before the Great War, but that event gave a tremendous impetus to commercial production, so much so that the older bye-product and natural forms have now fallen to second place in importance.

The merit of these artificials lies in the fact that they provide nitrogen in a concentrated form, convenient to handle, comparatively cheap, and readily assimilable by plant roots. Nitrates are the compounds which in the soil form most of the plant's source of nitrogen, and ammonium compounds are only one stage removed in this respect, being easily converted to nitrates by the action of certain bacteria in the soil. Each kind has its merits and de-merits, and to make the best choice it is necessary to consider these in connection with the soil and crop on which it is intended to use them. For instance, ammonium compounds are better suited to well-limed soils, while fertilizers containing a lime base have an advantage for general purposes on soils which are or tend to be acidic. Again, ammonium compounds seem to favour shallow-rooted crops such as barley or turnips, while nitrates have an advantage with more deeply rooting individuals such as wheat or mangolds. The reason lies in the fact that whereas nitrates steadily penetrate to the deeper and moister layers of the soil, ammonium compounds react with various compounds in the surface layer and are there fixed, although only temporarily. It is well to remember, however, that these differences are more relative than absolute, as ammonium compounds soon undergo nitrification when conditions are favourable and are converted into nitrates. The main characteristics of our chief nitrogenous artificials are set out in Table I., p. 116.

Sulphate of Ammonia.—Whether bye-product or synthetic, the properties of this material are the same. It is one of the most useful individual fertilizers. It is composed of small, even crystals, perfectly dry, which distribute well and evenly. Nowadays it is free from traces of acid, with the result that it can be kept for a long

TABLE I.—*Comparison of Nitrogenous Fertilizers.*

	Sulphate of Ammonia.	Nitrate of Soda.	Cyanamide.	Nitrate of Lime.	Nitro-Chalk.
% Nitrogen ...	20·6	15·5	20·6	13	15·5
Price per ton (1931)	£6	£10	£6 5s.	£9	£6
Unit price... ...	5s. 10d.	12s. 11d.	6s. 1d.	13s. 10d.	7s. 9d.
Physical Condition	Small, even, dry, free-running crystals, easily distributed	Moderately large uneven crystals	Fine, dry, dusty powder	Uneven crystals	Moderately large granules
Storage properties	Keeps well	Slightly hygroscopic and tends to cake	Keeps dry but, tends to cake	Very hygroscopic, stored in air-tight containers	Slightly hygroscopic
Behaviour in soil	Temporarily fixed in surface soil	Not fixed, easily washed out by excessive rain	Temporarily fixed	Not fixed, easily washed out	Partially fixed.
Effect on soil ...	Displaces calcium base which is washed out in drainage	Sodium base is fixed in clay, leading to poaching and loss of tilth	Contains free lime and conserves calcium base	Contains calcium base and so conserves that of soil	Contains free chalk and conserves calcium base of soil
Rate of application (cwt. per acre)	¾–2	1–1½	1–1½	1–2	1–2

time without losing condition. As it does not contain a metallic base, its conversion in the soil to nitrate entails the loss of a certain amount of the reserve lime which combines with the sulphate radicle and is washed out of the soil. The effect of this soon becomes apparent on soils which contain very little free lime. Its properties make it the most widely used nitrogenous constituent in fertilizer prescriptions.

Nitrate of Soda.—This substance is probably the most quickly effective of all forms of nitrogen. It does not contain so much of this constituent as its old rival sulphate of ammonia and falls behind it in respect of physical condition. The crystals are larger, more irregular and more inclined to cake, but on all these points it has of late years been improved. It is hygroscopic in tendency and so does not keep its physical condition so well. One of the characteristic features of nitrate of soda is the manner in which it functions, indirectly, as a potash fertilizer. The sodium base in it reacts with the complex mineral compounds in the soil and displaces potash from them. This characteristic gives it a special value with potash-loving crops such as the mangold. Another effect, but less desirable, connected with the same action is that its continued use on heavy soils or its liberal use in intensive farming on any soil, leads to the production of sodium clay, whose presence becomes evident in poaching, deflocculation, stickiness or loss of tilth.

Cyanamide—Cyanamide, calcium cyanamide, or nitrolim are various names used for one commodity, a nitrogenous fertilizer which has come into much prominence of late years. Its main features are a slower but more prolonged, and so more equable, action, and the possession of a valuable amount of free lime, incident to its commercial production. In practice it is sometimes found disagreeable to handle, and to avoid the possibility of it damaging germinating seeds or young crops it is advisable to distribute and work it into the land ten days or more before seeding. Its greatest value is as a nitrogenous manure on soils short of lime.

Nitrate of Lime.—This compound, like cyanamide, is one of the forms in which the nitrogen of the air is fixed by synthetic processes. It contains no free lime, contrary to the impression often created by its name, but as it contains the calcium base, it makes no inroads on the lime reserve of the soil and provides another useful fertilizer for acid soils and those which have only a small lime reserve. It is markedly hygroscopic and quickly becomes liquid on exposure to air, a fact well realized by anyone who has handled it. This characteristic causes it to enter the soil fairly quickly even in dry weather. It has the disadvantage, however, that it is necessary to pack it in airtight containers, and once these are opened, the contents must be used immediately, as the fertilizer rapidly loses its condition.

Nitro-Chalk.—This material is a blend of bye-product chalk and ammonium nitrate, in an even granular condition, and has

achieved well-deserved popularity of recent years, adding as it does a very desirable nitrogenous fertilizer to the list of those suitable for use on soils short of lime.

There are several other new synthetic nitrogenous compounds suitable for use as fertilizers. Although they are not as yet freely on the market, all of them have been experimently tried out, so that their characteristics are fairly well known. Some may appear in due course as common commodities, or they may be developed in connection with the new compound and concentrated mixed fertilizers which are now beginning to challenge the older and more familiar special purpose compounded manures. Such are

Muriate of ammonia	containing	26 per cent. of nitrogen
Nitrate ,,	,,	35 ,, ,,
and Urea	,,	47 ,, ,,

In the main they can be regarded as being similar to sulphate of ammonia, except in the matter of concentration.

Phosphatic Fertilizers.—Second in importance among the plant nutrients commonly added to the soil by means of fertilizers comes "phosphoric acid." This has its own peculiar effects on the growing plant. It fosters the development of the seedling and enables it to produce a more vigorous fibrous root system, which, in its turn, leads to a healthy growth above ground. It counteracts the weakening effects of excessive supplies of nitrogen, and helps to produce herbage of a much more nutritious kind. Finally, it quickens up the ripening processes in the plant, a useful and very real help with cereals in some circumstances.

In the following table are set out the composition and main characteristics of the fertilizers, whose chief value lies in their phosphate content. All natural forms of phosphate, practically speaking are insoluble in water and therefore slow in action. There are two ways in which this drawback is overcome in fertilizer practice. The raw material may be treated chemically in order to render it water soluble, or it may be ground very finely by suitable mills in order to give it a greatly increased surface area on which the dissolving or assimilating influences in the soil and roots of plants can operate.

The chief phosphatic fertilizers are compared on their salient features in Table II.

Superphosphate.—This is the most widely used phosphatic fertilizer, chiefly on account of its solubility in water and of its rapidity of action. Although it is a strongly acid compound, and is considered by many practical men to be a contributory cause of acidity in soils, expert opinion now inclines to the opposite view. Whichever view is correct, this fertilizer seems to give its best results in England on well-limed soils. Generally speaking, it is the most useful form to use in all arable farming and especially on light and chalky soils.

Basic Slag.—This bye-product of the steel industry still maintains its reputation in grassland improvement and on heavy soils.

TABLE II.—*Comparison of Phosphatic Fertilizers.*

	Superphosphate	Basic Slag.	Mineral Phosphate.	Bone Meal.	Steamed Bone Flour.	Dissolved Bones	Nitrogenous Guano	Phosphatic Guano.
Phosphoric acid %	14-16	11-16	26-36	21	28	16	7	20
Solubility ...	Water soluble	30-90% in citric acid test	20-40% in citric acid test	Partly citric soluble	70% in citric acid test	Partly water soluble	Partly citric soluble	Partly citric soluble
Physical condition	Granular	Ground to pass standard sieve	Ground to pass standard sieve	Roughly ground	Finely divided	Granular	Powdery and dusty	Earthy
Reaction ...	An acid salt	Alkaline, containing free lime	Containing free calcium carbonate	Containing free calcium carbonate		Acidic	Slightly alkaline	Neutral
Price per ton (1931)	£2 15s (14%)	£2 1s (14%)	£2 7s (26%)	£6 15s	£4 15s			—
Unit price ..	4s	3s.	1s 9d.		-		-	—
Rate of application (cwt. per acre) ..	2-4	5-10	3-6	3-5	3-5	3-5	2-3	3-5

Changes in steel-making processes have led to the production of various distinct types of basic slag of very varied agricultural value, as careful experiments have shown. The old citric acid test as a criterion of the value of slags has now returned to favour, and at the present time much English slag can be obtained with a guarantee of very high citric solubility. This is a point well worth the attention of buyers, although slags of doubtful merit under this test are not necessarily to be despised. It may be worth while to point out that materials like slag, which are insoluble in water, depend largely for their success on thorough incorporation with the soil. To ensure a result it is advisable to use a heavy dressing such as 8—10 cwt. per acre rather than 5 cwt., to choose a time when the ground is at its barest, and to harrow it well into the soil. Where the surface is covered with a mat of turf or excessive amounts of dead grass, careful attention to this point is essential, and drastic mechanical treatment is an essential part of the treatment.

Mineral Phosphates.—There are several forms of this raw material on the market, all finely ground. They function in much the same way as basic slag and have the merit of a higher content of phosphoric acid, and a much lower price in comparison. Generally speaking, they are less reliable than slag, but in certain circumstances, such as in regions of high rainfall and on soils short of lime, they will often give as striking if slower results.

Bone Products.—Raw bones contain fat, gelatine, calcium phosphate and calcium carbonate. The fragments are extracted by various means, such as steam or solvents, to obtain the valuable fats and gelatine, of which the latter particularly has a definite fertilizing value, on account of its nitrogen content. Bone meal is the residue after the extraction of the fat. It contains 21 per cent. phosphoric acid and 4 per cent. nitrogen, the gelatine not having been removed. The bone structure is still recognizable in the fragments. Steamed bone flour is the result of more drastic treatment. The gelatine being largely removed, the amount of nitrogen falls to 1 per cent., while the phosphoric acid rises to 28 per cent. At the same time the product is finer and more dusty. The presence of the nitrogen and the difference in composition between the two forms are reflected in their prices. Dissolved bones vary according to their origin. They are made in a similar manner to superphosphate by treating one or other of the above forms with sulphuric acid. The object is the same, namely, to render the phosphate soluble in water, though this conversion, owing to technical difficulties, is only partially accomplished. Bone products are mostly used in intensive cultivation, but are of general use on very light soils.

Guanos.—These fertilizers were among the earliest to be imported into this country, and they are still obtainable and used by many growers. They are the residues of the accumulated excreta of seabird communities, and so originally contain nitrogen, phosphoric acid and potash. If the deposit occurs in a rainless region,

all three will be present in quantity, and a nitrogenous guano may have an analysis of 11 per cent. nitrogen, 7 per cent. phosphoric acid and 5 per cent. potash. Such material is dry, dusty, light coloured and pungent with ammonia. But in places where rain falls the nitrogen and potash tend to be dissolved out and a phosphatic guano results. This is dark brown in colour, damp, earthy in smell and texture, with an analysis such as 1 per cent. nitrogen, 20 per cent. phosphoric acid and 1 per cent. potash. Most samples will vary between these two extremes. The great merit of guanos continues to lie in the gradual and equable nature of their effects, giving them a high value for the production of crops of good quality.

Potash Fertilizers.—Potash as a plant nutrient nowadays receives much more attention than it used to. In the plant it is found in the stems and leaves more than in the grain. Its function is to help to establish and maintain the plant in a healthy growing condition. It is intimately connected with the assimilation process in the leaves and in the production of starch and sugars. This helps to explain its beneficial effect on quality of fruit, grain and tubers. Plants suffering from lack of potash show a dull blue colour in the leaves and often a characteristic scorching. In cereals it often results in softness of straw and lodging. The range of potash fertilizers is small and the points of difference between the various kinds are not numerous. They are all easily soluble in water, but in the soil they are fixed by chemical reaction with the mineral complex and so are not liable to be washed out by rain. The chief features of commonly used potash fertilizers are shown in the table below.

	Muriate of Potash.	Sulphate of Potash	Potash Manure Salts.	Kainit.
Potash % ...	50	48	20–30	14
Condition ...	Large, uneven crystals, slightly hygroscopic	Small dry crystals	Uneven crystals, slightly hygroscopic	Uneven crystals, hygroscopic
Price per ton ...	£8 8s.	£10 4s.	£3 4s.–£4 6s.	£2 16s.
Price per unit ...	3s. 4d.	4s. 3d.	3s. 2d.–2s. 11d.	4s. 0d.
Rate of application (cwt. per acre)	½–1	½–2	1–3	2–6

Chlorides constitute the chief form of all the potash fertilizers, with the exception of the sulphate of potash. As for several crops, especially barley and potatoes, the sulphate radicle seems to produce consistently higher quality than the chloride, sulphate of potash is the most favoured form of potash for such purposes. Potash manure salts are available in standard grades, the more concentrated resembling muriate of potash, while the lower grades approximate more to kainit. This last is characterized by a high

content of common salt which has value for certain crops such as beet and mangolds, and is able to liberate some of the soil's reserve of potash. Kainit is of such low concentration that dressings of 3 to 5 cwt. per acre are not uncommon, and the addition of so much soluble saline material to the soil at seeding time is apt to have serious consequences on the germination of the seeds. It is advisable, therefore, to get it worked into the soil some time before seeding.

Chalk, Limestone, Lime, etc.—In the section dealing with soils, the subject of sourness was dealt with at some length. There are several commodities available for use in dealing with this problem.

Over considerable areas of the country chalk deposits are accessible. Rough chalk can be dug and spread on the land with great effect, as was done regularly in the past. The practice is being renewed, even in these times of depression. It takes 30—80 loads per acre to be effective, but the treatment may last for a corresponding number of years. Chalk contains 90 per cent. or more calcium carbonate, and weathers down moderately quickly. Crushed chalk is more effective, 4—8 loads per acre being a useful dressing. In some places the chalk is kiln dried and then very finely ground for sale as "ground carbonate of lime"; 30—40 cwt. per acre is a satisfactory dressing. Limestone is much harder material and is of little use unless it is ground to the fineness of basic slag and applied at the rate of 30—40 cwt. per acre. Precipitated chalk is a form of calcium carbonate produced in a very fine state of division in various industrial and water softening processes. When dried it commands a very high price amongst some intensive growers. It contains 95 per cent. or more of calcium carbonate. It can sometimes be obtained wet at a nominal cost when, providing that it does not need to be carted far, it proves a most useful form of lime, as favourable weather after leading will dry out the heaps and enable it to be spread easily.

Burnt Lime, Slaked Lime, etc.—Lump burnt lime is the purest lime usually obtainable. It needs to be slaked before spreading and may prove a wasteful and expensive form to use. Theoretically the ground form of burnt lime should be an effective means of surmounting this difficulty. It certainly provides a form which can be economically and effectively spread, but at a considerable sacrifice of quality in the product. Commercial lump burnt lime will normally contain 90 per cent. or more caustic lime, but the ground burnt lime bought by farmers much more frequently has a corresponding figure of 60—70 per cent. Ground burnt lime is unpleasant to handle and difficult to store, but given a good sample it is the cheapest and best in the long run; 15—20 cwt. per acre is a good dressing. It is caustic and slightly soluble in water and therefore is quicker and more drastic in its action. It is the best form for use on foul or heavy land, but should not be applied at times of active growth. At many lime-burning works, air-slaked residues are available at low prices. These are very like ground

burnt lime in their use and effect, bearing in mind their poorer analysis, uneven texture and milder nature.

The scope for discrimination on the part of purchasers of lime for agricultural use is shown by a comparison of various cases encountered in southern counties in the last four years. In all cases the price delivered on the farm is taken as a basis of comparison.

	% Caustic Lime.	% Calcium Carbonate.	Price per Ton delivered.	Estimated Comparative Values based on Composition, Cost of Grinding and Carriage.
Best lump burnt lime	87	3	47s.	47s.
Lump burnt lime ...	82	10	30s.	42s.
Ground burnt lime ...	70	10	32s.	37s.
	74	13	34s.	38s.
	36	26	37s.	29s.
.. ..	45	17	37s. 6d.	31s.
Air-slaked lime ..	48	6	27s.	24s.
Waste lime	47	9	21s. 6d.	25s.
Carbide waste ..	17	5	12s.	14s.
Ground chalk ..	0	97	37s.	28s.
.. ..	0	96	29s.	28s.
Coarse ground chalk	0	95	19s. 6d.	27s.

Compound Fertilizers and Special Mixtures.—Manure merchants and, in these days, many seed merchants, sell numbers of complete manures for various crops and for special purposes. Each one has its particular analysis and make-up. At intervals controversies rage on the question of the value of proprietary mixtures as compared with that of home mixed simple fertilizers. It is for the buyer to make up his mind whether the difference in value as assessed by unit values of nitrogen, phosphorus and potash, is serious enough to outweigh the undoubted merits of thorough mixing, friable condition and convenience for use which accompany the "special" fertilizer. There is, however, room for speculation as to whether two proprietary turnip manures of widely differing analysis can both be equally effective for his particular circumstances, or again, whether the last year's treatment of the field was such as to justify the use of a small amount of a single fertilizer only on this particular occasion. The best solution of the problem will probably be found in the employment of one or the other according to circumstances.

Concentrated Two- or Three-Constituent Fertilizers.—An answer to such disputes has come in an unexpected fashion quite recently. There has recently appeared on the market a range of concentrated fertilizers containing two or three of the main food nutrients in much greater concentration than is possible in mixtures of the older single-constituent fertilizers. This has been achieved by bringing them together in one substance, thus eliminating less valuable carrier materials. For instance, nitrate of soda contains 15—16 per cent. nitrogen attached to a soda base, while sulphate of potash contains 48 per cent. potash attached to a sulphate radicle. These two

fertilizers have money values to which the soda in the former and the sulphate in the latter contribute little or nothing. Nitrate of potash, on the other hand, contains 38 per cent. potash and 14 per cent. nitrogen in the same substance, so that a single hundredweight of it would go a long way towards replacing a hundredweight of each of the others. This is the characteristic of the new compound fertilizers. Materials such as nitrate of potash, nitrate of ammonium, phosphate of ammonium can be produced comparatively easily and can be blended in a molten condition with each other or with the more concentrated individual fertilizers to give a complete manure of almost any desired analysis, in a convenient granular condition, perfectly blended, easy to handle and store, readily available and without undesirable bulk. Such a material is produced in Germany under the name Nitrophoska, in several different grades such as the following, each of which is designed for a special purpose :—

	A	B	C
Nitrogen	17·5	15	16·5
Phosphoric acid	13	11	16·5
Potash	22	25·5	20

It can be seen from the figures for C that 100 lb. of this material would contain the equivalent in nutrients of 80 lb. of sulphate of ammonia, 120 lb. of superphosphate, and 50 lb. of sulphate of potash, thus reducing the weight of material handled from 250 lb. to 100 lb. Considering this point from another angle, a dressing such as 1 cwt. of sulphate of ammonia + 3 cwt. of superphosphate + 1 cwt. of sulphate of potash, involves the mixing and handling of 5 cwt. of material of a resultant analysis of 4 per cent. nitrogen, 8 per cent. phosphoric acid and 10 per cent. potash, figures which appear dilute when compared with the examples quoted above. Similar materials are now available in this country and should prove in practice convenient and efficient fertilizers.

The Use of Fertilizers.—The production of increased yields by the use of fertilizers may have no great attraction in times of depression and of low prices for farm crops, but so long as money continues to be spent on tillages there is an incentive to obtain higher yields by the use of fertilizers, which add little to the total cost. The money value of increments so obtained must be considered both as regards quantity and quality. For the latter especially, questions of paramount importance are the choice of type of fertilizer, the amount used, time of application, balance of constituents and varietal response for any one crop. It is to such points as this that experimental work is now being directed.

Fertilizer prescriptions can be drawn up for any crop in almost any circumstances. They will show great variations, but it may be of interest to indicate once more a few of the general points to be taken into consideration. The fundamental factors in the soil are its drainage and lime status, and unless these are satisfactory the use of fertilizers will never give its proper return. Next, different

classes of soil have their individual deficiencies, which should always be catered for in the use of fertilizers upon them. For instance, heavy soils as a rule are short of phosphoric acid, light soils of potash, and sandy or chalky soils of both. As regards the best use of individual commodities, burnt lime is the best form for heavy or foul land, while ground chalk is more useful on light land and in intensive crop-growing. Slag and mineral phosphates are best used for grassland or in districts of high rainfall and acid soils, while superphosphate is best used in arable practice and on soils rich in chalk. Of the potash fertilizers low grade forms such as kainit are most suitable for grassland or in cases of big deficiencies, while sulphate of potash is the best choice where quality of produce is the chief aim. Quick acting nitrogenous fertilizers provide the best top dressings and the most effective forcing agents, while organic refuses provide a means of raising the level of fertility of the soil and of getting good yields of high quality. Further, while ammonium compounds excel on well-limed soils, nitrate of lime and cyanamide are at an advantage on soils deficient in lime. Fertilizers which are soluble in water such as most nitrogenous salts, superphosphate, dissolved bones, the new compound manures, and all potash salts may be counted on to act quickly; refuses, slag, mineral phosphates and bones will act more slowly but give a more lasting effect. A final point to bear in mind is that all the soluble nitrogenous fertilizers are easily washed out of the soil by excessive rain, while for all practical purposes phosphates and potash may be regarded as fixed in the soil. The importance of this point lies in its bearing on the time of application. The type of farming and individual crops have already been mentioned (see p. 103), and the only further point of importance to take into consideration is the treatment which previous crops have received. It will be seen that this aspect of the rotation may result in big modifications in the treatment of individual crops. To consider a particular example, the root crop, swedes, mangolds or potatoes may receive 10—20 loads of farmyard manure and 5—8 cwt. of mixed fertilizers. The roots may be eaten on the land or carted off. In the former case, the land will be left with rich residues for the growing of a subsequent corn crop. Should this be barley, it may be advisable to give a small dressing of superphosphate to improve its quality. If the roots are carted off, the soil should produce a moderate crop of grain of good quality, or it may be of such a type as to respond to a 2—3 cwt. dressing of suitable barley manure. In the case of a second corn crop, a general fertilizer is most probably advisable. Should the corn crop have been grown solely on the residues from the roots, a following seeds ley will benefit substantially by a 3—4 cwt. dressing of mixed phosphate and potash. Finally, the corn crop following the seeds, especially if it be wheat, will find adequate residues therefrom and at the most will need no more than an ordinary nitrogenous top dressing in the spring. The case of grassland can be considered in the same

manner, due attention being paid to the nature of the soil, its past treatment and whether it is to be used as a meadow or a pasture.

Unexhausted Manurial Values.—The varied availability and mode of action of plant nutrients in farmyard manure and fertilizers is recognized in the practice of valuation for compensation for materials used on the farm on the occasions when it changes hands. Purchased feeding stuffs contain considerable manurial constituents. It is common practice to value on the assumption that in stall-feeding 40 per cent. of the nitrogen and 75 per cent. each of the phosphoric acid and potash are found in the manure, and that the effect of these is spread over two crops. These assumptions, together with the analysis of the feeding stuff and the unit values of nitrogen, phosphoric acid and potash, in the fertilizer market give the compensation value per ton of the feeding stuff consumed. If this is fed on the land, less wastage of nitrogen takes place and 70 per cent. of it is allowed in valuing the manurial residues. Similar reasoning may be followed in the case of straw sold off the farm, but in this case a figure has to be arrived at for the value of straw more as regards its physical effect in farmyard manure than on its chemical composition. In the case of purchased fertilizers, the subject is more difficult on account of the lack of satisfactory experimental data and the needs of various soils and crops. Generally speaking, longer residual values are allowed on grassland than on arable, but one may encounter all ranges between the extreme cases of one hundredweight of sulphate of ammonia with no residual value, and 80 loads of chalk with effects lasting many years.

Purchase of Fertilizers.—A purchaser of fertilizers is nowadays fairly adequately safeguarded by law. The Fertilizers and Feeding Stuffs Act operates to ensure his being supplied with adequate description of most commodities as to their nature and analysis, and provides him with the means of obtaining satisfaction in cases of dispute. According to the class of fertilizer offered, he is provided by the vendor with its percentage composition in respect of nitrogen, phosphoric acid soluble in water, insoluble phosphoric acid, potash, calcium oxide and calcium carbonate. The vendor is allowed limits of variation in his figures to set off against the inevitable deviations in the composition of various substances in bulk. For instance, the description of a basic slag as containing 12 per cent. phosphoric acid and 90 per cent. passing the prescribed sieve, is adequate to cover a range of 11—13 per cent. phosphoric acid and 85·5—94·5 per cent. fineness. It is useful to be able to compare prices with analysis, as this affords a criterion of comparative values, although, as has been pointed out, it is unfair to press the argument too far. The unit value of a single constituent fertilizer is taken as the price per ton divided by the percentage of the constituent present, the "unit" being 1 per cent. of a ton. The use of this scheme can be seen by reference to the lists of prices published in the Journal of the Ministry of Agriculture and other periodicals, at regular intervals.

The following books are recommended in connection with this chapter :—

Fertilizers and Manures. A. D. Hall. John Murray, London.
The Feeding of Crops and Stock. A. D. Hall. John Murray, London.
Manuring for Higher Crop Production. E. J. Russell. Cambridge University Press.
Collected Leaflets on Manures and Manuring. Ministry of Agriculture. London.

CHAPTER VI.

SEQUENCE OF CROPPING.

PRIMITIVE tillage farming in all parts of the world is, and in the past has always been, associated with a simple sequence of cropping. In the typical case a section of grass or light scrub-covered land is cleared and cropped with the same or similar crops until it ceases to yield profitable returns, either because of the exhaustion of fertility or because of the accumulation of weeds.

In the former case the cultivators move on and break up another virgin area ; in the latter the same practice may be adopted or they may introduce a bare fallow to kill the weeds and then crop the land as before. The former practice was probably adopted in primitive times in Britain. The latter practice was typical of the farming in California when wheat growing was first developed in that country during the latter part of last century. It is equally typical of the present sequence of farming in the Prairie provinces of Canada where continuous cereal crops are interrupted by bare fallows. As the needs of a community increase and farming becomes more intensive some definite sequence is developed, thus in the Manorial period of this country " when each man had his rood of land " the three-field system was developed. In this, autumn corn was followed by spring corn followed in the third year by a bare fallow after the stock had grazed the stubble of the previous crop through the winter and spring periods.

At this period of British farming, when the fields were divided into a series of narrow strips, each occupied by a different cultivator, the need for a rigid yet simple rotation was paramount, since every field would have become a patchwork of crops if each cultivator had been allowed to crop his " lands " as he pleased. When " Enclosure " followed, the need for a rigid system of cropping for purposes of maintaining fertility still persisted, though to a lesser degree, and with the introduction of clover by Sir Richard Weston, turnips by Lord Townsend and the drill husbandry by Jethro Tull the four-course system was developed and thereafter formed the basis of English farming until the end of the nineteenth century. During the latter part of this period the introduction of many types of artificial manure and the knowledge of how to use them rendered the rigid four-course rotation no longer necessary for the purpose

of maintaining fertility, and the Agricultural Holdings Acts of 1908, giving tenant farmers freedom of cropping, finally overthrew the idea that a rigid rotation was essential to arable farming. The introduction of the motor tractor, giving much greater speed of manipulation of tillage operations, further reduced this necessity.

At the present time most arable farmers, when asked what rotation they adopt, will reply that they follow no fixed rotation but at the same time when further questioned will agree that they adhere more or less closely to an orderly sequence which is capable of alternative application as circumstances seem to warrant. It is for this reason that the present chapter is entitled "Sequence of Cropping" rather than "Rotation of Crops," the heading adopted in earlier editions of this book.

The objects to be attained by a definite sequence of cropping may be considered under the following headings:—

(1) The increase or maintenance of fertility.
(2) The economical distribution of labour through the year.
(3) Convenient sequence of the crops.
(4) The control of weeds.
(5) The control of plant diseases.
(6) The special circumstances of the farm.

1. The Increase or Maintenance of Fertility in the Soil.—Whether it be considered from the point of view of the nation, the owner, the occupier or the farm labourer, there is no condition (except that the farming system is attended with profit) of greater importance than that the fertility of the land be maintained or increased, because upon this mostly depends the power of the soil to produce future crops.

Fertility of the soil, in the sense in which the word is here used, is governed firstly by the supply of humus and the nitrogen which it contains and secondly by the supply of certain available minerals especially lime, phosphates and potash. All soils, whether they be cultivated or uncultivated, are continuously undergoing changes brought about by chemical, physical and biological actions. Some of these changes lead to an increase of fertility, others to a decrease. The sum of the changes in ground covered with vegetation and not cultivated generally leads to an increase of the humus and therefore to increased fertility. Under arable conditions the su[illegible] changes generally result in loss of humus and therefore [illegible] fertility.

Most tillage operations tend to increase the aeration or ventilation of the soil so that oxidation is encouraged. By this the humus is decomposed and the nitrogen which it contains is converted from an insoluble to a soluble form. In this condition it is available for absorption by plant roots. At the same time tillage and the consequent aeration of the soil tends to encourage the solution and availability of the mineral plant food in the soil. Plant foods, when in this soluble condition, are liable to loss in two ways; either

they may be absorbed by plant roots to form part of the structure of roots, stems, leaves or fruits of the plants growing in the soil, or failing this, they may be carried away in solution by the excess rain-water draining through the land. In the former case such parts of the plant as are removed from the field at harvest result in loss to the field of the plant-food elements which they contain, whilst other parts, such as roots, stubble, broken leaves, etc., are left on the field to be reincorporated, together with the plant food they have taken up, in the soil.

When crops are consumed by stock on the field a comparatively small portion of the elements of plant food is retained in the structure of the animals, and the greater part is returned in the fæces or in the urine to the land. In the same way when harvested crops are consumed by stock in the yards bedded upon straw, etc., the resulting farm-yard manure contains a large portion of the plant food removed in the crops consumed and used as bedding, and if carted back to the land it returns to it the plant food which it contains. In the making and storage of farm-yard manure, however, it must be remembered that considerable losses of nitrogen and smaller losses of minerals are liable to occur, so that the efficiency of the return of plant food is not so great by this method as when the crop is consumed on the land where it is grown. It will thus be seen that loss of fertility is greatest in the case of those crops such as cereals or potatoes which may be sold away from the farm, intermediate in the case of crops which are consumed in the yards and made into dung (provided the dung is subsequently returned to the land), less in the case of crops consumed on the land, and least of all in green crops which are ploughed back into the land where they are grown.

Some crops, either because of the greater penetrative power of their roots or because of the more efficient tillage which they receive, extract from the soil larger amounts of plant food than others. A comparison in this respect between barley and mangolds shows that the latter extracts from the soil very much larger amounts of plant food than the former and is to this extent more exhausting. Root crops generally require and do in fact extract from the soil considerably larger quantities of plant food than cereals. Root crops, however, are generally heavily manured and frequently consumed by sheep on the fold, so that the fertility of the land is increased during the root crop. For this reason root crops are generally regarded as renovating crops, whilst cereals are exhausting crops because they are not heavily manured and because the whole crop is cleaned from the field. Leguminous crops in like manner extract from the soil more mineral plant food than the cereals and in this respect are more exhausting crops. They also obtain very much larger quantities of nitrogen than the cereals—a 2-ton crop of clover hay will contain approximately four times the amount of nitrogen contained in a wheat crop consisting of 30 bushels of corn and 30 cwt. of straw—but the nitrogen of the leguminous crop is mainly

obtained by the nodules on their roots not from the soil itself, but *from the air in the soil. This greater accumulation of nitrogen,* therefore, by leguminous plants does not result in loss of fertility, but on the contrary is the most potent means of accumulating fertility. When the roots and stubble of such crops are ploughed back into the soil, and still more when the stems and leaves are consumed on the land, the nitrogen content of the soil is largely increased.

The growth of peas and beans under arable conditions and of white clover under pasture conditions thus leads to large accumula tions of nitrogen in the soil.

2. The Economical Distribution of Labour through the Year.—In framing a sequence of cropping the economic use of labour requires to be considered under two headings :—

(i) Distribution of labour through the year ;
(ii) The elimination of unnecessary or unproductive work.

In farming practice it is generally necessary to employ the greater part of the labour continuously throughout the year. It is not so feasible in farming as in other businesses to discharge men when a busy season of work is finished and expect to find them available for work when the busy season comes on again. If such methods are attempted it will be found that the casual labour is either very inefficient or very costly. Continuous employment must, therefore, be found for the greater part of the labour employed. Now no single crop requires continuous labour throughout the year, but each crop requires labour and sometimes a great amount of labour at special seasons. Thus the wheat crop in this country is planted in autumn and harvested in late summer and therefore demands labour mainly during October and November for planting and in August and September for harvesting. Very little labour is expended on the crop at other seasons. The potato crop has requirements for labour at other seasons ; the land may be ploughed in winter, planted in spring, cultivated and sprayed in early summer, harvested in autumn and marketed in winter. It will be seen that these two crops require labour at dissimilar periods and for this reason are suitable crops to combine in a sequence of cropping. Other crops have their own seasonable requirements of labour. In framing a sequence of cropping, therefore, great care must be given to see both that too great a congestion of work does not arise at any one period of the year, for nothing prejudices successful farm management so badly as being unable to do work at the right time, and conversely that the periods when little or no labour are required is not too protracted. A certain amount of labour can generally be economically utilized upon matters of upkeep such as drainage, fences, roadways, etc., which do not require attention at very precise times, but these are limited in quantity, and any excess of labour beyond these requirements is unproductive.

Another point in the economical utilization of labour is illustrated

in the cartage and use of farm-yard manure. At the present time the cost of labour involved in the cartage and spreading of this product is very high. If the dung is utilized for the production of crops which are saleable at good prices all is well, but if it is utilized in the maintenance of fertility for the production of ordinary farm crops such as wheat and beans the cost may bear no relation to the benefits received especially when the field lies a long distance from the site where the dung is made. A sequence of cropping which involves the carting of farm-yard manure for ordinary farm crops must so far as possible be avoided and in its place the fertility of outlying fields should be maintained either by the use of green manuring or by the use of temporary pastures which are grazed during part of the year.

In some measure the arguments relating to the need for a uniform distribution of man labour apply to the distribution of horse labour, since horses have to be fed all the year round whether at work or not. And it is important to plan so that the requirements for horse labour are not greater than the supply. But the application of the argument is not so great in this case at the present time when tractors are generally available to overtake the arrears of heavy work, but they apply none the less in some cases as, for example, in the harvesting of large areas of root crops. It is also true that if a surplus of horse labour occurs at any period the cost of feeding and maintaining some of the horses can be reduced to small limits by turning them out to grass.

3. **Convenient Sequence of the Crops.**—The sequence of cropping should in the first place satisfy the condition that each successive crop follows the preceeding crop with a convenient interval of time to carry out the necessary acts of tillage in order to secure an adequate seed-bed. The interval should not be too long nor too short. If too long, not only is time wasted but soluble plant food may be drained away whilst the land is bare. If too short there may not be sufficient time for tillage and weathering to enable a good seed-bed to be prepared and the following crop has to be planted either in an unfavourable seed-bed or too late. Thus wheat planted in November can be conveniently taken after potatoes harvested in September or October, but it cannot be advantageously taken after roots folded in November because December is not a favourable month for planting wheat. Similarly it would be bad policy to grow turnips planted in May or June after potatoes harvested in October because of the waste of time and of plant food during the interval.

The growth of and the tillage for some crops leaves the land in a suitable condition for the growth of other crops. The deep cultivation generally given to all root crops leaves the subsoil mellow yet firm for the subsequent growth of corn crops. Clover and other leguminous crops enrich the soil with nitrogen which provides plant food for subsequent crops, thus wheat can be advantageously grown after clover or beans. The fibrous roots

left in the land after the growth of a "layer" consisting of mixed grasses and clover provides, when ploughed up, an open texture which is very favourable to the growth of potato roots, which do not have great penetrative power.

4. **The Control of Weeds.**—Different crops have different habits and are planted and managed in different ways. Some crops such as wheat are planted in autumn others such as barley are more frequently planted in early spring, whereas the root crops are generally planted in late spring or early summer. Each of these seasons of planting are favourable to the growth of some weeds and prejudicial to the growth of others.

Some crops such as the cereals are generally planted in narrow rows so that their foliage may cover the surface quickly and thus tend to crowd out annual weeds. Other crops such as beans or turnips are planted in wide rows so that intercultivation of the crop for the purpose of killing weeds may be carried out whilst the crop is young. These different conditions favour or prejudice different weeds. Some crops have a dense foliage which tends to shade the ground and others have a much more open foliage amongst which weeds grow freely. Barley is illustrative of such open foliage and is liable to contain many annual weeds. Oats make a much denser foliage and tend to smother weeds. A crop of marrow stem kale with its broad horizontal leaves forms a perfect canopy of foliage when well grown and completely smothers small weeds. A mixed crop of beans, oats and tares similarly forms a dense smothering canopy.

Some crops hold the land for a longer or shorter time than others. These different conditions also favour some weeds and prejudice others. A wheat crop, growing from October to August, favours the growth of perennial weeds such as couch and thistles much more than a root crop planted in April or May and harvested in October. A long layer, during which the land is uncultivated for three or four years, is very disadvantageous to the growth of annual weeds but may lead to the spread of perennial weeds. On the other hand the taking of two crops during the year with the additional cultivations which are entailed may, if the cultivations are well executed, help to eradicate both annual and perennial weeds.

In addition to these general considerations certain crops are introduced into the sequence of cropping with the special purpose of enabling weeds to be killed or a bare or bastard fallow be taken. The crops specially suited to the killing of weeds are the root crops, including turnips, swedes and other Brassica crops, as well as mangolds and potatoes. Such crops facilitate the killing of weeds in three ways: they are generally planted late in spring or early in summer, so that there is a long interval of time after the previous corn crop, which gives time for cleaning operations either after harvest or in the spring before planting; they are planted in wide rows so that both horse and hand hoeing for the destruction of weeds can be easily carried out; they produce horizontal foliage,

which, when the plants are established, shades the ground and checks the growth of weeds.

5. **The Control of Plant Diseases.**—Diseases and pests are likely to accumulate on land continuously cropped with the same crop. Thus land is said to become "clover-sick," owing to the accumulation in the soil of one or more of several disease-producing organisms, when cropped too frequently with red clover. Turnips and other Brassica crops in the same way are likely to fail with finger-and-toe and potatoes to suffer more from potato blight if grown too frequently. Other crops, for example, wheat and mangolds can be grown frequently and indeed continuously in some cases and continue to yield satisfactory crops, as in the case of the successive crops on the Broadbalk field at Rothamsted, but even in the case of wheat continuous cropping may lead to the accumulation in the ground of white heads (Ophiobolus) and other diseases and the practice is, therefore, undesirable.

If an interval of time is allowed to elapse between the taking of two similar crops, the diseases and pests find no host plant and die out or migrate. The interval of time necessary to complete the process must of course depend upon the life cycle of the disease or pest. Self-sown plants may of course continue the infection in cases where these occur.

6. **Special Circumstances.**—The conditions prevailing upon one farm vary widely from those prevailing upon other farms and the sequence of cropping must be varied accordingly. Climate is an important factor to be considered in deciding what crops to grow. The dry climate of the eastern counties is favourable to tillage farming and especially to the cereals, wheat and barley. The moister and cooler districts of the west and north are more suitable to the growth of temporary and permanent pasture and, if cereals are grown, to oats rather than wheat or barley. Smaller differences in local climate, as for example those associated with altitude, aspect, liability to frost, etc., may favour the growth of one crop and make it advisable to vary the sequence.

The character of the soil is largely responsible for the success or failure of different crops. On light soils with easy drainage the land warms up quickly in spring, growth is rapid and harvest is early. Tillage and intercultivation is comparatively easy and root growth is facilitated. On the other hand fertility is not generally very high and in periods of dry weather crops may suffer from lack of water. These conditions are specially favourable to the growth of malting barley, provided the land is not too dry. They are not so favourable to wheat and oats, but rye grows to advantage on the lightest and driest of soils. Root crops of all descriptions can be easily cultivated and easily harvested or folded if desired. Such soils are specially favourable to sugar beet, turnips, and to early potatoes. They are not so suitable to main crop potatoes because lack of fertility and of moisture frequently result in small crops. Light soils, especially in moist districts, are favourable to catch

cropping because seed-beds can be quickly obtained, and growth is rapid.

Chalky soils are frequently light and easy to cultivate in which case they favour the growth of barley and roots and in addition are very favourable to the growth of such leguminous crops as peas, sainfoin and many clovers. If thin, they are not very suitable to wheat, beans or potatoes.

Heavy soils are difficult and costly to cultivate. Their texture does not facilitate the production of good seed-beds nor the easy growth of plant roots. They are not favourable to the harvesting of root crops in bad weather. As a result of these conditions relatively few crops can be successfully grown upon them and the crops which can be successfully grown are generally possessed of a vigorous root system.

Wheat and beans both have strongly-growing roots and these crops grow to advantage on clay soils. Mangolds have deeply-growing roots and grow well on clays, but potatoes cannot be grown successfully both because the soil is unsuitable to growth and because it is impracticable to harvest them in wet seasons.

Red clover and white clover together with certain grasses used in temporary pasture such as rye grass, cocksfoot and rough-stalked meadow grass grow freely and abundantly provided the land is not allowed to become waterlogged, and since such pastures entail little annual expenditure for labour and management they can be grown economically upon heavy land.

Loamy soils are suitable to the growth of nearly all crops because both fertility and water supply are generally good, consequently the crops produced are generally large. Both barley and wheat grow well, so do beans, and large crops of good quality potatoes can generally be produced. Very large crops of turnips and mangolds can be grown though the folding of the former in wet weather sometimes damages the texture of the land. Red clover and other leguminous crops grow freely and many vegetable crops can be incorporated in the sequence of cropping. For these reasons it is necessary in planning a sequence of cropping to give careful consideration to the suitability of the crops to the soils on the farm.

The stock policy adopted on the farm will make varying demands for food and bedding, especially for the winter months, and the cropping sequence will need to be framed to provide for these. If sheep predominate a sequence of folding crops must be provided. If dairy cows, a winter supply of hay, mangolds and such winter green crops as marrow kale may be required. Provision must be made to guard against periods of shortage of grass during summer droughts by the growth of lucerne, green maize, cabbage, etc. Conversely the amount of stock kept and the amount of farm-yard manure produced may influence the sequence of cropping by rendering it advisable to introduce a larger area of potatoes, green vegetables, etc., to make more profitable use of this bye-product of the farm.

Local markets and local demands for special produce may make it desirable to vary the sequence of cropping. Proximity to a large provincial town or to a seaside resort will create a good demand for vegetables of all sorts which can be cheaply delivered if the distance is short. In such cases these crops should find a place in the sequence. Proximity to racing stables will create a good demand for hay and straw. Proximity to a sugar factory reduces the cost of transport on sugar beet, especially if the fields on the farm adjoin the main road or canals. In such cases the sequence of cropping should be planned accordingly. In other cases, where farms and fields are inaccessible for one reason or another, provision should be made in the sequence of cropping for a greater proportion of the produce to be fed to stock or for the growth of crops which are not bulky in character so that transport is facilitated. Wheat growing in the Prairie Provinces of Canada illustrates this case. These and many other considerations peculiar to the circumstances must be taken into account when planning the sequence of cropping on any farm.

Examples of Crop Sequences.

1. CONTINUOUS GRAIN CROPS.—The simplest sequence of cropping which can be adopted is one in which the same crop is grown continuously on the land. The system adopted by the Canadian farmer in the Prairie Provinces is closely akin to this. It consists of successive grain crops interrupted only by an occasional bare fallow for the purpose of killing weeds when these become excessive. The system is justified only because it is essentially a case of mass production. These farms are situated so far from their ultimate market that the cost of marketing any bulky crop or any product produced in small quantity would be greater than its value. Continuous cereal growing leads to the production of dry grain in large quantity. Organization provides for the bulking, the transport and the marketing of it at low cost so that it may compete on favourable terms with other cereals on the world markets.

From all other points of view the system is to be condemned. The natural fertility of the soils, which is initially very high in these areas, is slowly but surely dissipated, partly by the removal of the grain without the return of any manure and partly because, since no stock are kept and the straw is valueless, this is burnt up after threshing. The land, which when first broken is free from arable weeds, quickly becomes infested with wild oats and many other typical grain weeds. Continuous cereal growing also tends to the accumulation of the fungus diseases and insect pests peculiar to these crops.

The labour requirements are badly distributed through the year. There are two intensely busy periods, the first being the preparation and drilling of the land in spring after the long period of frost and snow of winter, the second the harvesting and threshing of the crop before winter sets in.

The entire saleable output of such farms is confined to the three cereals, wheat, barley and oats, the value of each of which is interdependant, so that the prices of all rise and fall together; consequently the farm income is liable to great fluctuations.

The Norfolk or Four-Course System.—This system runs as follows:—

Roots—turnips or other folding crop or mangolds.
Spring corn—barley or oats.
Leguminous crop—clover or mixed seeds or peas or beans.
Autumn corn—generally wheat, rarely rye.

From the middle of the eighteenth century until the beginning of the twentieth this system formed the basis of a very large portion of English farming, and for the conditions prevailing during the larger part of this period was a well-nigh perfect system especially in the drier districts.

At a time when artificial manures were non-existent or but little understood it provided for the maintenance of fertility at a reasonable standard, so that the owner was insured against depreciation and the occupier assured of good crops in the future. It provided continuous employment of labour throughout the year: the autumn was employed in harvesting some of the roots, in preparing and planting wheat, in ditching and hedging. The winter was employed in threshing corn, in feeding stock in the yards and folding sheep, in ploughing for roots and for barley. The spring was employed in completing the ploughing, in drilling spring corn and clover seeds, in cleaning the root land, and in spring-tillage of corn crops. The summer was occupied in drilling and hoeing root crops, in the hay harvest and the corn harvest. With one-fourth of the land devoted to roots, this system required a relatively large staff of labour, but during this period farm wages were very low so that this drawback was not very serious. The system provided two cash crops, namely, the wheat and the barley and at the same time an abundance of food for livestock, namely, the roots and the clover hay as well as the cereal straw for litter so that ample farmyard manure could be produced to maintain fertility. One criticism may be advanced against the system, if literally employed, namely, that when land is cropped with clover once in four years it is liable to fail from the accumulation of various diseases. This, however, can be easily remedied by substituting some other leguminous crop in place of red clover; thus peas may be grown on light land, beans on heavy land, or trefoil, sainfoin, white clover, etc., may be substituted.

The system was specially suitable to light land farming in dry districts where the trampling of the sheep on the fold caused no detriment to the soil texture and where the sheep manure provided the folding was properly controlled, improved not only the manurial but also the textural condition of the soil.

Where the system was applied to heavy land, sheep-folding in winter and early spring was liable to injure the texture and so

prejudice the growth of the barley. In this case the roots needed to be folded early or carted from the land for consumption in the yards. On the heaviest types of clay land the root crop was eliminated and its place taken by a bare fallow.

In wet districts of the north and west, which are less favourable to barley, an oat crop was taken in its place. If potatoes were to be grown they could be planted in place of some of the roots.

At the present time the four-course system, owing to the high cost of labour, cannot be economically employed, but it has been modified and extended in various ways to meet the needs of modern farming and indeed most modern systems may be shown to be modifications of the old Norfolk system.

The simplest modification is that in which two corn crops are taken in succession after roots. With the feeding of linseed cake and other highly-nitrogenous concentrates in place of home-grown corn, to the sheep folding upon the roots, it was found that the land after roots became over-rich for barley. The crop was then liable to be coarse and sometimes laid, with the result that the grain was less valuable for malting. On the other hand the residue of sheep manure after the growing of one barley or other cereal crop is sufficient to fertilize a second barley crop. This second barley crop, though generally producing a smaller yield than the first, is more uniform in character and quality, and, if the growth of the crop is likely to be too weak, modern manuring with artificials can be applied to the required amount without prejudicing the uniformity and quality of the sample. This five-course system increases the acreage of corn crops from one-half to three-fifths of the cultivated area and consequently increases the amount of saleable corn. At the same time the area of roots is reduced from one-fourth to one-fifth so that a saving of labour can be effected on this crop. This means that a smaller proportion of the land is cleaned each year, and weeds are more likely to accumulate, a difficulty which can be easily overcome by cultivating the first corn stubble quickly after harvest, a practice which will at the same time cause the self-sown grain to germinate, subsequently to be killed by ploughing, so that these plants may not grow as an impurity in the second corn crop.

This system is specially suitable to fertile soils of medium texture where first-class barley can be grown and marketed at good prices.

An alternative method of converting the Norfolk system to a five-course system consists of taking a second corn crop, generally winter oats, after the wheat crop as follows :—

Roots
Barley
Seeds
Wheat
Winter Oats

This system is more applicable to heavy land upon which it is

difficult to fold sheep so that most of the roots are carted and where barley of malting quality is rarely obtained. Upon such soils winter-planted crops such as wheat and winter oats can be grown to better advantage than spring crops.

Like the previous five-course system the area devoted to corn is increased and roots decreased and similar advantages and disadvantages accrue.

In districts and conditions peculiarly favourable to the growth of cereals, the Norfolk system may be extended to a six-course system by the introduction of corn crops in both places in the sequence as previously discussed :—

Roots or Fallow
Barley
Barley
Seeds or Beans
Wheat
Oats

In this case roots are reduced to one-sixth of the area so that the labour requirements on these is much reduced and the cereal area increased to two-thirds.

The liability to weed accumulation is further increased and must be dealt with by efficient stubble cleaning after harvest. In times when the only source of cultivating power was that provided by horse labour this concentration of work might have been difficult of accomplishment, but, with tractor-power available, cultivations can be so rapidly executed that this difficulty need not now arise. In cases where this rotation is applied to heavy land the roots may be in part or in whole substituted by a bare or bastard fallow, the latter consisting either of trefoil or other crop cut for hay or silage, or folded before being fallowed in July.

When cereal prices are high this system provides good returns under suitable conditions, but is relatively unprofitable when cereal prices are low.

A six-course system commonly adopted for potato growing in some southern districts runs as follows :—

Roots
Barley
Seeds
Potatoes
Wheat
Oats

In this case potatoes are taken after clover, a very favourable tilth for this crop, partly because of the accumulation of nitrogen by the clover, but especially because the fibrous roots and stubble of the clover produce humus and a good texture in which the potatoes revel. It also provides a longer period of growth for the clover, and mixed grasses if any, in autumn than in the case where the layer must be ploughed up for wheat sowing in autumn.

This system provides for two cleaning crops, roots and potatoes, in six years so that the land can be easily kept clean and the potatoes can be cashed to advantage, as well as the three cereal crops.

Another six-course system suitable for the growing of potatoes is that called the East Lothian system, which runs as follows :—

Roots
Barley
Seeds
Oats
Potatoes
Wheat

In the district of East Lothia and other parts of Scotland to which it is applied, conditions are often more favourable to the growth of oats than of other cereals, and the crop can commonly be marketed to advantage for oatmeal. This crop is therefore taken after the seeds where it benefits from the accumulated fertility of the clover roots. As the oats are sown in the spring a longer grazing period is available on the clover stubble. In other respects its advantages are similar to the previously described six-course system.

In the Norfolk and similar systems the clover and other "seeds" crops have been described as one-year layers, growing for one year only. These systems have proved specially suitable to the drier districts of eastern and southern England in times when cereal prices were remunerative because in these districts the second growth of red clover in the first year can often be profitably harvested and cashed as seed and because weeds and wireworms tena to accumulate in second and third year seeds to the serious disadvantage of subsequent crops.

In moister districts the layers are commonly kept down for two, three or more years as in the following system :—

Roots,
Barley or other cereal,
"Seeds" for two, three or more years,
Wheat or other cereal.

Expressed in this way the system may be said to be the Norfolk system in which the "seeds" have been extended for two, three or more years, but this does not give a full picture of the system which may be more graphically expressed by the term "Alternate Husbandry."

In alternate husbandry the land, having been cropped for some years, is laid down to temporary pasture for a number of years, after which it is again broken up and cropped. Whilst the land is under temporary pasture many advantages are obtained. The land becomes filled with fibrous roots of grasses, clovers, etc., which, together with the turf, greatly help the texture of land when next broken up. The fertility of land, whether measured in terms of humus or of nitrogen, can be rapidly increased and in minerals also

if lime, phosphates or potash are added by way of top-dressings. The increase of fertility is very largely associated with the presence of wild white clover and its proper management by suitable mineral manuring as well as by appropriate grazing. The annual cost of management is greatly reduced because after the initial seeding (generally in the preceeding corn crop) no further expenditure is required by way of seeding or of cultivation save an occasional rolling or harrowing, and the cost of harvesting is very small in the case of hay and non-existent when grazed. It must not be forgotten, however, that the capital required for laying-down as well as for fencing and water supply for stock may be very high. During the period of temporary pasture the production of herbage, whether for hay or for grazing, is generally very great, and sometimes in the case of inferior land several times greater than permanent grass upon similar land. This is due to more favourable textural conditions of the soil and to the use of more prolific species of plants than those occurring in the old pastures. Coincident with this is the fact that stock thrive much better upon new temporary pasture than upon old pasture not only because of the more abundant herbage but also because the new temporary pasture is free from stock diseases.

When the temporary pasture is broken up and recropped the fertility, stored up by the nodules of the leguminous plants, by the organic residues of the grass and clover roots and stems, by the top-dressings applied to the pasture and by the droppings of the animals grazed on the pastures, is utilized for the production of crops. This accumulated fertility is mainly in an organic condition which, under arable conditions, becomes progressively available for plant growth. In this way the fertility stored during the period of temporary pasture can be utilized in the production of cash crops and when this is partially exhausted the land may be again laid down to temporary pasture and the process repeated. It will be noticed under this system that fertility is maintained without the use of farmyard manure, the carting of which, especially to outlying fields, involves the use of much manual and horse labour. Any farmyard manure produced on the farm can thus be utilized upon fields near the buildings or devoted to special cash-producing crops, such as fruit and vegetables, if desired.

This system of alternate husbandry has been practised in the moister districts of England and especially in Scotland for many years, and has received special attention since the discovery of the outstanding value of wild white clover as a nitrogen-collecting plant, and the use of basic slag and close-grazing in stimulating its growth.

Similar systems of alternate husbandry are practised in the Canterbury Plain of New Zealand and are attended with similar labour-saving and economical advantages. In this case the root crop, if any, generally takes the form of rape which is used for grazing by sheep and lambs. In the drier and hotter wheat-growing

districts of Australia a similar system has been developed with the use of subterranean clover in place of wild white clover for nitrogen-collecting purposes, in conjunction with other suitable pasture plants. In the drier eastern districts of England temporary pastures have often been unsuccessful in the past, either because the pasture thinned out badly after the first year or because the crops grown after the pasture was broken up have been seriously damaged by wireworms, etc. The first of these difficulties has in most cases been due to the use of unsuitable mixtures of seed or to faulty management since in recent years many excellent temporary pastures have been obtained in these districts and have produced not only excellent yields but yields which are less subject to the effects of drought than permanent pastures in such districts. The second difficulty has not yet been adequately solved, but with good management and careful choice of crops to succeed the layer need not be so disastrous. None the less it is a danger to be anticipated.

The conditions to be considered, in framing a sequence of cropping, discussed in these pages, by no means exhaust the possibilities of the case. Many variations great or small may be necessary to meet the need of special circumstances but enough has been written to show the importance of this phase of the farmer's business.

CHAPTER VII.

FARM CROPS

Wheat.—Although there are at least thirteen species of wheat grown in different parts of the world, ranging from *Triticum monococcum*, a species cultivated in mountainous districts in Europe and producing only one grain per spikelet, to the widely-cultivated forms of *Triticum vulgare* with from three to five or more grains per spikelet, only two species, *Triticum vulgare* and *T. turgidum*, are of economic importance in the British Isles to-day.

The head (inflorescence) of wheat is described botanically as a "spike-like inflorescence" and is comprised of a series of spikelets arising alternately and in succeeding positions from the nodes of the stalk or "rachis" of the inflorescence. Each spikelet consists of two fairly tough outer coverings, the "glumes," and a series of two to five or more florets arising on a short branch, the "rachilla," originating from each node of the rachis. Every floret consists of two coverings, the outer or dorsal, and the inner or ventral "palea," which enclose the true flower comprised of an ovary with a feathery bifurcating stigma, and three stamens which are borne on fine filaments and when ripe appear above the ovary.

The glumes vary in colour, shape, and size; they may be covered with short hairs "pubescent" or be free of hairs "glabrous." The apex of the dorsal palea may be extended aerially to form an awn when the ear is described as bearded, or it may possess no awn when

it is described as beardless. Again, the whole ear may be short and compact, *i.e.*, " dense," as a result of the short distance between the nodes, or when they are farther apart and the ear becomes longer, it is described as " lax."

The grain exhibits numerous variations in size, shape, colour and in the character of the endosperm. It may, for instance, be long and narrow with a distinct groove or furrow on the ventral surface or short and plump ; it may have a red or white outer skin or " pericarp " or some colour intermediate to these two ; finally, the endosperm may exhibit a white, starchy or a smooth, steely appearance.

In addition, there are what are termed "physiological characters" such as earliness and lateness in ripening, and, more important still, resistance or non-resistance to various diseases.

The species *Triticum vulgare* furnishes the varieties of what are known to-day as the " bread wheats," the cultivation of which is spread over all countries with temperate climates. The bulk of the European, Canadian, American and Australian wheats belong to this species.

In general the varieties of this species are characterized by medium length to long straw, which is hollow throughout its whole length, excepting at the nodes ; the ear may vary from dense to lax, and may be bearded or beardless ; in some cases the grain is red and in others white, in some cases the glumes are covered with short, fine hairs or " felted " and in others entirely free of hairs or " glabrous." One feature distinguishing varieties of this species from those of other species is the keel of the glume which in this case is extended for only a short distance from the apex or beak, and in its lower portion is smooth and rounded.

The spikelet generally contains from three to five florets.

Economically, however, it is the physiological characters and others defined as quantitative, that demand the greatest attention. Included in the former are immunity and susceptibility to disease, earliness and lateness in ripening, resistance or non-resistance to cold and other effects which together comprise the total of winter conditions, adaptability to conditions of soil, and to different degrees of soil fertility.

It is not improbable that no large potential difference in yield exists between the leading varieties of *T. vulgare* in cultivation in the British Isles to-day, or, in other words, if all the varieties are grown under conditions to which they are best suited they will not exhibit wide differences in yield. But yield of grain is in reality the resultant of a large number of contributory causes, and it is not until they are all operative in the same direction that maximum results can be obtained. For instance, a crop of the highest promise may be so badly attacked by rust that the resulting grain is only half its normal size and weight, or again the size and weight of grain may be reduced by lateness in ripening.

It is true, as just stated, that ultimate yield is a resultant of

all possible causes operating within the life period of a plant and that the final yield alone is a criterion of value, but such a conclusion should be received with caution. It is quite possible for an average figure of yield over a period of seasons to be unduly influenced by one good year with the result that that year and probably the average of the series of years under discussion shows a profit, whilst the remaining individual years either show no profit or an insufficient one. Thus, in addition to the yield of grain the evaluation of varieties should be made on a series of characters such as resistance to disease, hardiness, strength of straw, and finally consistency of yield.

During the past thirty years the quality of the wheat grain has received considerable attention, largely because the Canadian and American wheats, which from 1870 onwards reached this country in yearly increasing quantities, were found to be superior to English wheats for bread-making ; they produced more loaves for a given weight of flour and were, in addition, characterized by a larger volume and a higher degree of aeration than loaves obtained from home-grown wheats. Generally speaking, the grain of the best bread wheats is characterized by a high protein content, but some characters of the proteins, such as resiliency and the power of retaining the gas formed during the fermentation of the dough, are more important than their total quantity.

Grains of good baking varieties when cut across exhibit a hard, steely appearance, whilst those of inferior varieties present a less sharply definite surface, and are white and mealy. For this reason "strong" wheats are sometimes known as "steely" and "soft" wheats as "mealy," the definition in this case being an allusion to the character of surface of the interior when cut across.

Although the English wheats were usually "weak" they produced a larger quantity of grain per acre than the "strong" wheats in use in Canada and America. By crossing Red Fife, a "strong," and Browick, a "weak" wheat, the variety Yeoman was produced. This is a very close approximation to the Fife parent in quality on the one hand and to Browick in yielding capacity on the other. The rust-resisting variety Little Joss was produced by crossing Ghirka, a rust-resistant form of Russian origin with Squarehead's Master, a highly yielding English variety.

The few varieties of the species *Triticum turgidum* such as Rivet or Cone found in cultivation in the British Isles are characterized by long, fine, pendulous, resilient straw which is filled with pith for a distance of a few inches from the base of the ear. The ears are usually strongly awned, the glumes are grey in colour and felted, and the keel of the glume is strongly developed and extends from the apex to the base, at which point instead of extending without interruption to the rachis there is a distinct "collar" developed.

Rivet, which is an old English sort, and other varieties of this description, can be grown successfully on cold, wet clay soils—soil conditions to which many more modern wheats are entirely

unsuited. On such soils Rivet produces a high yield of grain and the plant, because of the small leaf surface offered to the action of wind and rain, and the resilient straw, is able to maintain itself erect under conditions inimical to other varieties.

For bread-making Rivet possess little or no value, but as a poultry grain it is not inferior to any native varieties.

The most important varieties of *T. vulgare* in use to-day are Yeoman, Little Joss, Queen Wilhelmina and Squarehead's Master, all being winter varieties and all, with the exception of Queen Wilhelmina, being red-grained.

Of the origin of Yeoman something has been said already, but in addition to the quality of the grain and the yielding potentiality of the variety, the character of the straw, which stands well, is a further claim to distinction. Yeoman succeeds best under conditions of high soil fertility, a feature which may be taken full advantage of since it is unlikely to become lodged. Although Yeoman has been slightly out-yielded by one or two modern varieties, it maintains its superiority in grain production on the most fertile soils.

Little Joss does not possess such good milling and baking qualities, but it has high grain-yielding propensities, especially on light soils. Previous to its introduction there was no high yielding variety suitable for this class of land ; by reason of this attribute, combined with a high degree of resistance to yellow rust, Little Joss has played a very important part in wheat growing in the British Isles.

Squarehead's Master derives the first part of its name from the appearance of the ear, being approximately the same width when looked at either full face or sideways. It is a red-chaffed and red-grained variety of high yielding capacity and has maintained a prominent position in wheat growing during the past fifty years.

Squarehead's Master shows a preference for soils of lower fertility than those required for Yeoman and on these it is relatively more productive than that variety. On the other hand it does not respond to intensive manuring so well as Yeoman.

The grain of Squarehead's Master has very little value for bakery bread-making.

Queen Wilhelmina is a Dutch wheat which, since its introduction thirty years ago, has achieved a very important position amongst varieties grown in the British Isles by reason of its high yielding propensities. It is white-grained and the grains are fairly large and plump and consequently favoured for poultry feeding. As a bread-wheat it is greatly inferior to Yeoman, but on the other hand it has proved a most desirable form for biscuit-making for which purpose it is much in demand.

The straw is of medium length and fairly strong. Wilhelmina is best suited to soils of rather above average fertility, and thus finds a place between Squarehead's Master on the one hand and Yeoman on the other.

In addition to these winter wheats there are a few varieties

which on account of their earlier ripening habit are used for spring sowing. Such are Red Fife and Red Marvel. The former is always a valuable milling wheat because of its high quality, but both varieties are somewhat weak-strawed and neither approaches any of the winter sorts in yielding capacity. Consequently their uses are limited largely to conditions arising out of an inability to utilize the winter sorts.

POSITION IN ROTATION.—With the exception of Little Joss, which suits light soils, the varieties in general use succeed best on heavy to medium loams ; in the case of Rivet this may be extended to include cold, wet clays. In the crop rotation, wheat frequently succeeds ley, and where fallowing is practised it may follow this treatment of the soil ; it also often succeeds beans and sometimes roots and potatoes.

Wheat is responsive to nitrogenous fertilizers and as the straw is much stronger than that of the other cereals and the grain does not suffer readily in quality as a result of high soil fertility, full advantage can be taken of these facts to treat the crop intensively. Wheat is responsive to phosphates also, especially when in a readily available form, and the addition of potash may be beneficial in minimizing the incidence of fungus diseases such as mildew.

A usual mixture of artificial fertilizers is therefore :—

1–1½ cwt. sulphate of ammonia.
2–3 cwt. superphosphate.
2 cwt. kainit.

The fact that wheat is an autumn-sown cereal raises the question of the most suitable time of application of a mixture of artificial manures. Between the time it is sown and the end of January in the following year the vegetative development of the plant is relatively small and it cannot profitably utilize much nitrogen, whilst in addition, should the autumn rainfall be heavy, the sulphate of ammonia may suffer considerable loss by drainage. On the other hand it is realized that one source of additional yield in a crop is an increase in the number of the well-developed tillers a plant can support. But to produce their maximum contribution to the general yield the tillers must appear and develop as nearly as possible concurrently. The possibility of the plant taking advantage of an abundant supply of nitrogen at an early stage in its career is thus important, and while a loss by drainage is avoided by advancing the date of spreading the ammonium sulphate, it may be unwise to defer the application too long.

Superphosphates greatly encourage root development, and early application of this fertilizer in conjunction with kainit is consequently necessary.

In practice superphosphates and kainit are applied together before, or at the time of sowing, and sometimes with a small portion of the nitrogen, but at other times without any of it. When a portion of the nitrogen is applied in autumn the balance should be applied as early as possible in the following year.

Barley.—It has been observed previously that the spikelet of wheat consists of two large well-developed glumes which may in some species enclose one, but more generally two or more florets, each capable of producing a grain. In oats also there are two large glumes, and the whole spikelet consists usually of two or more florets, although there are varieties having a large proportion of one-flowered spikelets. In barley, on the other hand, the glumes are relatively small and insignificant, and the spikelet consists of one floret only. Again, although there are species of barley characterized by naked grain, such as is found in the majority of wheats, in the forms of barley usually grown in this country the paleæ, which form the skin of the grain, are fused with the caryopsis, or true kernel.

In barley as in all the other cereals there is a large number of species and varieties, but when dealing with the home-grown crop the varieties of importance are confined to two main species—*Hordeum polystichum* or six-rowed barley, and *Hordeum distichum* or two-rowed barley.

In the six-rowed barleys three fully fertile spikelets arise from each node of the rachis; the same arrangement obtains in the two-rowed barleys, but in this case only the middle or median row of the three spikelets is fertile—the other two containing stamens but no ovary. The median rows of spikelets in the case of both species have their ventral surfaces, *i.e.*, the surface with the furrow, opposed to the broad side of the rachis. The other spikelets are attached to the node nearer the edge of the rachis and in six-rowed forms the grains are consequently not absolutely symmetrical in longitudinal section, but slightly twisted. As to each set of three spikelets there is only one median grain, there are altogether at each side of the rachis in six-rowed varieties, one row of median and two rows of lateral spikelets, or in the whole ear two rows of median and four rows of lateral spikelets. In two-rowed varieties, on the other hand, there is one row of fertile and two rows of infertile spikelets on each side of the ear or two rows of fertile and four rows of infertile spikelets altogether.

Between these two species there is a further species, *H. intermedium*, with six rows of fertile spikelets, but in this case the grains of the lateral are much smaller than those of the median rows and are, in addition, frequently either awnless or possess very small awns.

Each of these main groups is sub-divided on the basis of the length of the internode, or distance between the points of attachment of the spikelets on the rachis. Thus, there are dense and lax six-rowed barleys, *i.e.*, barleys with the spikelets set close together, and others with the grains set at a great distance apart on the rachis, whilst similar sub-divisions occur in the two-rowed divisions.

Instead of referring to the two-rowed barleys as dense and lax-eared, however, they are usually described as broad and narrow-eared. These two sorts form the bulk of malting barleys grown in the British Isles.

Of the six-rowed barleys there are some possessing a certain degree of winter-hardiness which in consequence are grown as winter sorts, but the area devoted to them is small compared with that devoted to the ordinary spring sorts of two-rowed barley.

Now, although only about three-fifths of the home-grown crop is used for malting, by far the greater portion of the total crop is grown in the hope of producing a sufficiently high standard of quality to be utilized for that purpose. It is thus important to know exactly the characteristics of a good malting sample, and more particularly the conditions determining the final quality of the grain. A good malting barley is one containing a high percentage of starch and a small quantity of protein—that other important constituent of all cereal grains. It is from the starch that the brewer ultimately obtains maltose, and it is this material that later, when in solution and acted on by yeast, produces a fermented liquor.

Apart from good " condition," by which is meant freedom from excessive moisture and a sweet smell, injuries to the grain sustained during thrashing, such as the removal of the germ, skinning or fracture of the grain, all operate against a high price. Again, a good malting sample should exhibit evenness in size of grain and in degree of ripeness, and be free of extraneous matter such as weed seeds.

A good malting sample always exhibits certain well-defined physical features ; the skin is evenly coloured and very finely wrinkled ; the groove on the inner side of the grain is well-filled, and the grain consequently tends to be circular rather than oval in section whilst the interior of the grain exhibits a white, mealy appearance. Chemical examination shows that the best malting barleys are almost invariably relatively low in protein, that is, in those substances containing nitrogen. The valuation of a sample on the basis of the physical features just mentioned is, therefore, an accurate guide to intrinsic malting value.

It may be considered that the question of the character of the grain is being over-stressed, but when it is recollected that the difference between a good sample and one which fails to reach a sufficiently high standard to be used for malting is often at least twenty shillings per quarter, the importance of quality in barley will be adequately realized.

During the past twenty-five years a great deal of attention has been devoted to the question of malting quality in barley, and as a result of different researches its true meaning is more clearly understood, and many of the contributory influences are now capable of more accurate definition. Although there are many minor characters of a sample of good malting barley, a high starch content is fundamental, and we shall not be very wide of the mark in studying conditions contributing to the production of grain displaying this character.

The first and most important condition influencing the quality of the grain is unquestionably the weather, and, strangely enough,

such extremes as very dry, sunny weather, and wet, sunless weather, operate against high malting quality. In the former case, owing to insufficiency of moisture, the plant dies prematurely before the translocation of starch from the straw to the grain is completed, whilst in the latter, the absence of sun and the excess of moisture lead to the grain being insufficiently ripened. Under both conditions the grain is thin and on sectioning exhibits what is described as a "steely" interior, in contra-distinction to the "mealy" interior associated with well-filled and fully-ripened grain. Thus barley, like oats, produces the best results in seasons of moderate rainfall; neither very dry nor very wet years are really good. When considered in its relation to definite periods in the life history of the plant, it is found that a moderately dry time immediately before and after sowing is beneficial; likewise, a fairly liberal supply of moisture during active growth in late April, May and early June. After flowering and during filling, a moderate supply of moisture is desirable, and some again, preferably in the form of light showers, when the grain is almost completely ripe.

The next contributory condition is the soil, and here it is found that, regardless of the rainfall, heavy soils do not yield the best malting samples. These are produced invariably on the fairly rich loams and in years characterized by a moderately heavy rainfall. Truly light soils produce excellent barleys in years of sufficient rainfall, but usually fail badly in dry years. Taking a long series of years in review medium loams produce the highest yield and the best quality of grain.

Following weather and soil, the next important influence is that of variety. The numerous experiments with malting barley conducted during the last twenty-five years have been instrumental in demonstrating real differences in malting quality between varieties. Largely as a result of the comparison of varieties on this basis, especially when viewed together with the yield of grain, the number of varieties of barley in general use to-day is small. A quarter of a century ago, the narrow-eared Chevallier, which in its day marked a notable advance on the varieties in use previous to its appearance, was extensively grown in the British Isles. The grain of Chevallier was beautifully shaped and coloured, and produced good malt. Unfortunately the variety was weak strawed and thus liable to lodge when grown on rich soils or in seasons of heavy rainfall, which induced excessive vegetative development. As a result of comparative trials, Chevallier was gradually replaced by Archer, and still later by a hybrid, Spratt-Archer, which was obtained by crossing Spratt and Archer.

Archer, in addition to being a shorter and stronger-strawed barley than Chevallier, is more prolific, and the grain, although not so attractive in appearance, produces excellent malt. Spratt-Archer is still stronger in the straw than Archer, and produces more grain, which, in addition to being brighter coloured, exhibits a slightly superior malting quality.

A survey of the broad-eared varieties for the same period reveals similar large changes. Before the appearance of Goldthorpe in 1899, Spratt was the leading variety of this class. Although noted for its stiff straw and peculiar ability to thrive on soils containing a large proportion of organic matter, Spratt never produced outstandingly good malting material. When Goldthorpe appeared it quickly established itself as excellent malting barley, and it is doubtful whether any subsequently introduced variety has excelled it in this respect. For the heavier classes of soil, Goldthorpe, like all broad-eared types, is superior to the narrow-eared barleys. In the ease with which the ear breaks off the straw when fully ripe, Goldthorpe exhibits a serious defect which subsequently led to its supercession by Plumage-Archer, another broad-eared barley, obtained by crossing Plumage, a barley of the Goldthorpe type, and Archer, which does not suffer from this defect. Plumage-Archer, like Goldthorpe, is particularly suited to the heavier barley soils, and whilst being somewhat earlier in ripening than Spratt-Archer it can be grown further North than that variety.

Position in Rotation.—Barley is a plant of rapid growth and development and this, coupled with the facts that it is essentially a surface feeder and unable to make a good defence against weeds, determines its place in the crop rotation. It is most commonly sown after a root crop, and usually produces the best results when it follows turnips, swedes or mangolds, rather than potatoes. Occasionally, barley is sown after another corn crop, generally wheat or sometimes barley itself, but this is usual only on land in a fairly high state of cultivation.

Sowing.—There is a good deal of experimental evidence in support of the practice of sowing as early in the year as the condition of the soil and the state of the weather permit. A seed-bed, which by its condition of tilth permits the seed to be deposited at approximately one depth and at regular intervals, is the one to be aimed at, and the exact date of sowing after, say, January, is immaterial, provided drilling is carried out when the land has reached this state. The quantity of seed varies somewhat with the nature of the variety and of the soil. The usual rate of seeding is 2½—3 bushels per acre, but in the case of high tillering barleys such as Spratt-Archer, the smaller quantity is sufficient. On light lands the rather heavier rate is preferable, while on heavier land and on land in good heart, 2½ bushels is ample seeding.

It should be unnecessary at this time to point out that the seed used should possess a high percentage of germination, and in most years there is no difficulty in farmers obtaining sound, reliable seed with a germination of at least 90 per cent. It will be recollected that evenness in size of grain and in degree of ripening are essential conditions of high market value, and to obtain these characteristics in the resulting crop, evenness in the growth of the plant from the very commencement should be aimed at. A great many samples of seed exhibit a high germinating capacity, but in many cases,

and especially after a wet harvest, the germinative energy of the seed, that is, its rate of germination within a specified period, is low and irregular.

The shoots of young plants obtained from such seed consequently appear above the surface of the soil at varying intervals and establish a difference in degrees of development, which, being maintained up to harvest, is exhibited finally in the varying degrees of ripeness of the grains composing the bulk.

Because of their possible influence on the subsequent quality of the crop, other characters of barley seed have received attention in recent years. It has been shown, for instance, that the varieties in general cultivation require rather different treatment in the malthouse to secure the maximum of "extract" from them, and that consequently in bulks of grain composed of two really good malting barleys losses may be sustained by too long a period on the malt floor in the case of one variety or too short a period in the case of the other. These facts are well known to most barley buyers, and if they have evidence of mixture in samples offered to them their price is reduced accordingly. But this general position is aggravated by the fact that no two barleys ripen at exactly the same time and a mixture in a crop may, under some conditions, result in a proportion of unripe grain, a feature readily detected by the buyer who appraises the value of a sample accordingly.

Thus, varietal purity in seed barley becomes a very important feature. As evenness in size of grain and in the degree of ripening are important, it is desirable to use seed of even size, and such evidence as there is available rather points to the superior value of the more nitrogenous grain for use as seed. Although it is a practice with some growers to purchase seed of lots of barley that have received awards on a malting quality basis, it by no means follows that the resulting crop will exhibit the same degree of quality. That depends on a series of conditions, some of which have been indicated already, and only in so far as the variety is one of proved potentiality in regard to quality can the grower hope to influence the character of his crop by the seed he purchases.

Provided the land is clean, the subsequent cultivation of the crop is fairly simple and consists of harrowing with a light harrow and rolling. Harrowing should be timed to be performed when the plants show two or three tillers, and if done when the soil is drying after rain, the crop will be greatly stimulated. In addition to its direct effect on the crop itself, harrowing will either kill or by exposure to the sun so injure surface weeds as to render them innocuous to the barley.

Some judgment is required in choosing the best time to roll for if done too early it may seriously check the young barley plants, whilst on the other hand, if it is done too late, it may injure the rapidly developing tillers.

Rolling should be done when the soil is in a drying condition, and with either a plain or a Cambridge roller, according to the

state of the soil. The latter type is preferable if the crop is suffering from wireworm or other grub attack, for it compresses the soil well round the plants and so renders the progress of this pest from plant to plant more difficult.

In cases of severe drought, rolling may be repeated once or twice at intervals of seven to ten days. If for any reason hand-weeding is necessary, it should be done before the crop is far advanced in growth, for barley will not stand much rough handling.

Cutting.—There is usually an interval of about six weeks from the time of the ear first appearing to the time of full ripeness, but the exact time varies greatly with the nature of the weather during the period of filling. If there is a good deal of sunshine alternating with showery weather about the time of full ripeness, then the final stages of ripening are remarkably rapid ; on the other hand, in the absence of sunshine and dews at night, these stages are more prolonged.

It is a golden rule in barley growing to leave the crop standing until it is completely ripe, a condition which is indicated by the entire absence of any trace of greenness in the straw, and better still, by the grain, which at this stage should exhibit a distinct mellowness and a very finely wrinkled skin. Grain, which when rubbed out in the hand assumes a shiny, ricey appearance, is definitely unripe. It is a better practice in every respect to allow the crop to be over-ripe than to cut it prematurely. With varieties such as Spratt-Archer the crop is not fully ripe until the ears turn completely down with the awns pointing to the soil in a line parallel with the straw. Care should be taken not to cut the crop when it is at all wet, for dampness round the bands of the sheaves, although not of itself harmful, may cause heating in the stack, which, although it may not proceed so far as to injure the vitality of the grain and so destroy its value for malting, is likely to give it an undesirable smell.

After stooking, the crop should be allowed to remain in the field until the sheaves are thoroughly dry. During this period an alternation of rain and sunshine mellows the grain, but sometimes causes a good deal of difference in the colour from the two sides of the sheaves. If it is thought necessary, the difference in colour may be obviated by rebuilding the stooks with the previous inside of the sheaves now placed to the outside. This, however, is not a procedure to be recommended in unsettled weather.

Provided the crop is quite dry, it may be thrashed from the field, or it may be stacked and left for thrashing until some subsequent time.

Thrashing.—Injuries to the grain such as skinning, removal of the germ, or too close thrashing resulting in the tip of the corn being exposed, should be carefully avoided, for they detract seriously from the value of the grain for malting. A little of the beard left on the grain is no drawback, and is, in fact, regarded as an indication of careful thrashing.

Damage to the grain is usually caused by the breast of the concave of the thrashing drum being set too closely to the revolving drum, but too rapid thrashing, failure to open the sheaf sufficiently, and the passage of grain into the drum without its complement of straw, are frequently contributory causes. Screening should be carried out with care and every effort made to secure a sample in which the grains are all of approximately the same size, for this is a feature to which the buyer attaches considerable importance. Good screening is secured (1) by opening the screen sufficiently and by removing grains which become lodged between the wires in the course of thrashing, and (2) by feeding the thrashing machine at such a rate as to obtain an easy and regular passage over the screens, for when a thrashing-mill is over-fed much of the grain fails to reach the operative part of the screen at all. A little large corn in the screenings causes infinitely less ultimate loss than a small portion of screenings in the good corn.

MANURING.—When barley is sown after a root crop it rarely requires further assistance, for the residuum of the manures applied to the roots is sufficient to carry it. On occasions, however, it is sown after a previous straw crop, either wheat or oats, generally the former, and some form of artificial dressing is then desirable.

It may be regarded as an axiom that the effect of nitrogenous manures when applied to barley is to increase the amount of nitrogen found ultimately in the grain, a definitely objectionable feature in grain intended for malting ; nitrogen also has the effect of unduly prolonging the ripening period. If the land to which the nitrogen is applied is already well supplied with phosphates and potash in forms available to the plant, a better balance of the three plant foods is obtained, and the quality of the grain for malting is unlikely to be impaired. This latter condition, however, presupposes a knowledge not always possessed by the farmer, nor readily determined by mere inspection of the soil. Consequently, unless such knowledge is available, the safest procedure is to use a balanced manure, that is, one in which all three of the manurial constituents, nitrogen, phosphates and potash appear. The nitrogen will stimulate the growth of the plant, whilst the phosphate and potash will both operate to secure the good filling of the grain.

These three manures may be applied as a mixture in the following quantities per acre :—

1 cwt. sulphate of ammonia.
3 cwt. superphosphate.
3 cwt. kainit.

After sheep fed on, the land is often too rich to grow good malting barley, largely by reason of the excessive quantity of nitrogen present. In such cases the application of a dressing of superphosphate alone is well worth trying, and if successful it may be supplemented by a small dressing of kainit on a limited area. Generally, however, it will be found that the phosphate alone is sufficient to rectify the effect of the excessive quantity of nitrogen.

Oats.—In general form the oat plant is similar to the other cereals; it is fibrous-rooted, the culm is erect and divided into nodes and internodes, and the leaves are divided into sheaths and leaf blades. The inflorescence, however, presents several features differing from those of wheat, barley and rye. In these, the divisions of the rachis are so small that they are only fractions of an inch, whilst in oats they are measured in inches; moreover the spikelets in oats are not borne directly on the rachis, but either on branches of varying length arising directly from the nodes of the rachis, or on secondary branches arising from the primary branches. The manner in which the spikelets are joined to the pedicels, or small branches, is important, and forms, indeed, one of the features utilized in distinguishing different species. Thus, in some species there is a distinct cavity at the base of the grain, the edges of which are well defined, and frequently bear a ring of strongly-grown hairs. The extremity of the pedicel is expanded into a knob which fits into this basal cavity, the two thus simulating a ball-and-socket joint. Such an arrangement is found in *Avena fatua*, the wild oat of cultivated land, and in *Avena sterilis*, another wild form, indigenous to the countries bordering the Mediterranean. On ripening, the tissue connecting the pedicel and grain separates naturally, and the grain thus detached from its pedicel is shed on to the soil, thereby assuring continued propagation.

In *Avena sativa*—the species to which most of the cultivated varieties found in the British Isles belong—there is no sharp division of the tissues connecting the spikelet and the pedicel, and the grain when fully ripe separates from the pedicel by a distinct fracture of the tissues uniting the two.

The wild oat, *Avena fatua*, is further distinguished from the cultivated form, *Avena sativa*, by the possession of a strongly grown, twisted and kneed awn, which is invariably present on all the grains of the spikelet. An awn is developed in many varieties of *Avena sativa*, but then only on the lower grain of the spikelet which may consist of two or more grains.

Avena strigosa, another species, must be mentioned here, for some varieties of this group are the oldest forms known in Britain, and are still cultivated in mountainous districts in Wales and in some of the western districts of Scotland.

The grains of all the varieties of *Avena strigosa*, or the "bristle-pointed" oat, are small, and their attachment to the pedicel is similar to that found in *Avena sativa*. Instead of a more or less indeterminate end to the dorsal palea, however, the tip of the husk is extended into two long, fine, awn-like projections, and each grain of the spikelet carries a well-developed, twisted and kneed awn. The various forms of oats of this species flourish in Wales and Scotland on soils where none of the varieties of *Avena sativa* can be grown with any degree of success. The grain is small, but the straw is long, fine and abundant, and makes excellent fodder.

Although considerable but persistently smaller quantities of oats

are used in the form of porridge, oat cakes, etc., for human consumption, by far the greater quantity is utilized for stock feeding, consequently it is with this ultimate method of disposal in view that the value of the oat grain is determined.

Now in barley the paleæ, or coverings of the grains, are fused with the caryopsis or kernel, and it is impossible to detach them from the grain when it is dry; even after soaking in water a separation can be made only with difficulty. In wheat, on the other hand, the kernel is separate from the paleæ and may be removed readily on rubbing the ear through the hand. In oats, although the paleæ envelop and so effectively protect the caryopsis against the weather, they are not actually attached to it in any way.

If the true kernels of wheat and oats are examined chemically the largest differences in composition are found in the quantity of crude fibre and ash, both of which are higher in wheat; the fat is invariably higher in oats, and the amounts of crude protein are similar in both cereals. But oats when used for cattle food are usually consumed unhusked, and it is thus the composition of the whole grain that demands most attention.

Comparing wheat and oats on this basis the differences in composition are considerable, but they are centred mainly around the crude fibre, which frequently amounts to as much as ten per cent. of the weight of the whole oat grain. When it is recollected that the husk forms from 20—30 per cent. by weight of the whole grain, and that a third of the weight of the husk is fibre, the corresponding quantity in the whole grain is fully accounted for. After the fibre, the next largest difference is found in the crude fat, which is naturally much lower in the whole grain than in the kernel of oats, but is still higher than that found in wheat. The crude protein also suffers some reduction, whilst the ash is increased.

In all respects, excepting that of fibre, the oat grain is a well-balanced food. To a large extent fibre is indigestible, and therefore unable to function either in maintaining the body heat or in contributing to sustain the normal physical activities of an animal; it may, moreover, actually draw on more digestible foods for the muscular energy utilized in passing it through the alimentary canal. Thus it is that the quantity of fibre largely determines the feeding value of the grain; there are, of course, differences in the amount of the other substances, but these, so far as feeding value is concerned, are outweighed in importance by the quantity of fibre.

VARIETIES.—The number of varieties of oats in use has not undergone the same reduction as we have noted in the case of barley, and the farmer is consequently faced with the necessity of making a choice from an extraordinary large and bewildering collection of forms.

Fortunately, the varieties in general use display certain characteristics which may be used to arrange them in convenient groups. The largest and most economically important group is

that into which the majority of spring-sown varieties fall. In this group such oats as Abundance, Victory, Golden Rain, Record, etc., are included. These are all characterised by stiff, moderately long, upright-growing straw, with open panicular-shaped heads, and grain with a tendency to be relatively large and of average quality. They are all spring forms, which although they may possess a small degree of winter-hardiness, will not survive a hard winter. Similar to varieties in this group in most features except the character of the inflorescence, which is "one-sided," are varieties such as Black Tartary, usually grouped under the sub-species, *Avena sativa orientalis*; these also are spring forms with stiff, upright straw and grain of rather inferior quality. Beyond the fact that the primary and secondary branches are held stiffly erect and adpressed to the rachis there is no botanical difference between varieties of this sub-species and those with open panicles grouped under *A. sativa*.

A further group which, if of less importance than formerly, is nevertheless still valuable, is the one including Potato, Sandy, Longfellow, etc., all regarded as dual purpose varieties, that is, in addition to producing excellent grain, they yield an abundance of long, leafy, succulent straw of high value for stock feeding.

Finally, there is the group comprised of the true winter-hardy forms, such as Grey Winter and Black Winter, which of all the varieties in use in the British Isles to-day are certainly the most resistant to winter conditions. Of the two, Grey Winter is slightly superior in this respect; but both produce an abundance of long, fine straw, which unfortunately exhibits a marked tendency to weakness on most soils. The quality of the grain in both cases is excellent and distinctly superior to that of most of the spring varieties, such as Abundance, etc.

The value of the varieties of oats at present available to the farmer is not wholly determined by the characters of the straw and of the grain or by their ability to withstand winter conditions. A further valuable feature is their adaptability to definite conditions of soil and climate, which enables the grower to meet the requirements of his particular conditions. Thus, Potato, Sandy and varieties of similar character are most successfully grown in localities with relatively heavy rainfall and of moderately low temperature. Districts such as Northern Ireland, North-west England, and a greater part of Scotland are noted for the excellence of the Potato oats produced there. In the East and South-east of England, Abundance and Victory, but particularly the former, are the most successful varieties. In the West of England, Golden Rain, and in Wales, Record, are the most suitable varieties, whilst in the South-west, Black Tartary and varieties of similar character are preferred on less fertile soils. Being a somewhat late-ripening oat, Black Tartary is preferred in these parts for the additional reason that it is not necessary to harvest it until after the usually wet periods of August.

Position in Rotation.—The position of oats in the crop rotation varies greatly with the extent to which other corn crops are cultivated on the farm. In Scotland, and in many parts of the North of Ireland, for instance, where neither wheat nor barley is grown in large quantities, oats follow root crops, leys and, if necessary, oats themselves. Where both wheat and barley are grown, oats then usually succeed wheat or on occasions they may be taken after leys. As barley usually follows a root crop and wheat succeeds ley, the position of oats is largely defined by the demands of these two cereals rather than by what should be its own particular requirements.

Seed and Sowing.—Although there is a tendency nowadays to return to the earlier custom of broadcasting seed, especially in Scotland, oats are usually sown with the ordinary corn drill in rows of 4 to 8 in. apart. The quantity of seed used varies with the locality, the character of the soil, the variety, and the time of sowing. In some areas such as Northern Ireland, as much as six bushels and over may be used, but the general quantity is three to four bushels ; light soils require rather larger amounts than heavier soils. Varieties with high tillering capacities such as Potato, Sandy, Grey Winter and Black Winter may be more thinly sown than others such as Abundance, Victory, etc., which have a definitely less good tillering habit ; finally, early sown crops by reason of the greater tiller development resulting from the longer period allowed for growth, and because they are less liable to serious insect attack, require less seed than crops drilled later in the season, which secure neither of these considerable advantages.

The depth of sowing is to some extent governed by the character of the soil—the lighter soils, owing to the easier penetration of the soil by the young shoot, being able to sustain deeper sowing than heavier ones. As a general rule, however, a depth of from two to three inches is the most desirable, whilst anything less than this renders the plant liable to suffer from lack of adequate anchorage, and anything greater results in the vigour of the young plant being absorbed in penetrating to the surface of the soil.

Although there is no well marked tendency for farmers to use barley seed from well-defined areas, or from definite descriptions of soil, there appears to be some preference for oat seed from certain districts and soils. For reasons which have not been satisfactorily substantiated by actual experiments, Scotch seed oats have a distinct vogue in southern counties, whilst on chalk soils seed from the Fen districts is said to be desirable and *vice-versa*. Although it is unwise to ignore these long-established customs, it is equally undesirable to state them as practices meriting unqualified emulation. They are wide-spread practices and consequently merit attention, and, if possible, corroboration.

Seed should be sound and exhibit high germination and germinative energy ; the grains composing seed samples should be large and even in size. A mixture of large and small-sized seed is not

as productive as a sample in which the seeds are all large, for the large seeds produce larger and more vigorous plants than those resulting from small seed, and the stronger plants ultimately compete so strenuously for space and light as to seriously limit the ultimate value of the produce of the small seed. Nevertheless bulks of seed composed entirely of small-sized seed are capable of producing as heavy crops as large-sized seed under favourable conditions of climate, but as these cannot be predicted with certainty the use of large seed only is the safer practice to follow.

MANURING.—The character and the quantity of artificial manures applied to oats depend very much upon the character of the crop they follow. If, as is frequently the case, they follow ley it is rarely necessary to augment the store of food material resulting from the decomposition of the clover and grass roots and portions of stems. Similarly, if they succeed roots the residue of manures used with those crops is sufficient to carry one corn crop at least. But if oats follow a corn crop, then the addition of some artificial manure is necessary unless farmyard manure is available, in which case it should be spread on the stubble of the preceding crop as early in the autumn as possible and ploughed in.

Like other cereals, oats respond well to nitrogenous manures, but to obviate excessive vegetative development, which so often results in crops lodging, such manures should be augmented with soluble phosphates, preferably superphosphate, and small quantities of potash. A usual dressing is :—

1 cwt. ammonium sulphate,
3 cwt. superphosphate and
2 cwt. kainit per acre,

which should be applied either just before or at the time of sowing. In the event of insect attacks, such as frit fly, wireworm, or leather jacket a small dressing, say, ½ to 1 cwt. of nitrate of soda, may stimulate the growth of the crop sufficiently to carry it beyond the danger of complete destruction, but the use of such manures alone is always attended by the risk of over-growth, and later by lodging.

TREATMENT BETWEEN SOWING AND HARVESTING.—When oats are sown on ley land it is advisable to roll them immediately after sowing, preferably with a Cambridge roller, if the land is rough. Following this, the nature and the degree of treatment must be governed largely by the variety. Most of the spring oats such as Abundance and Victory, are characterized by what is termed an erect habit of early growth ; on the other hand, the true winter varieties exhibit a prostrate habit of early growth. Both these types of growth are in evidence at an early stage in the life-history of the plant. Now, whilst harrowing and rolling can be carried out with little or no ill effect to the varieties characterized by the prostrate habit of growth, the same operations may cause serious injury to the erect-growing forms unless they are performed at a much earlier stage. Although harrowing is desirable and unharmful to all forms,

it is questionable whether rolling of the erect forms might not be omitted or at least reduced to a minimum unless attacks of wire-worm and other insect pests make the operation a clear necessity.

Weeding is sometimes necessary, especially in the case of such weeds as thistles, and is carried out in a similar manner to that employed in the case of other cereals.

The methods of cutting and harvesting are identical for all the cereals, but where the straw is utilized for feeding, special care must be exercised to prevent loss in feeding value by heating in the stack. In districts characterized by heavy rainfall, and in Scotland especially, this is secured by the use of stack racks which permit the free circulation of air through the interior, thereby preserving both grain and straw in an excellent condition.

As by far the greater proportion of the oats produced in the British Isles is consumed on the farm, the necessity for close screening at threshing is not so imperative as it is with wheat and, more especially, with barley. Moreover, the small grains of an oat spikelet usually contain less husk than the large ones, and although they may detract from the appearance of a sample, their influence on the quality is beneficial. Any portion of the crop intended for seed, however, should be more closely screened to obtain an even-sized sample of large grain, the value of which for seed has been dealt with previously.

Rye.—Although rye is a very important crop on the Continent, its cultivation as a grain crop in the British Isles has almost ceased. Rye bears a strong likeness to the other cereals botanically, but possesses other features which give it an added value agriculturally. Thus, it is the hardiest of all the cereals and can over-winter under conditions of low temperature to which wheat even will succumb, it will thrive on the very lightest soils and under conditions of considerable soil acidity. It is not surprising, therefore, that it is found chiefly on very light sandy and gravelly soils, particularly in the east of England.

Rye grain is similar in composition to wheat and may be used for stock feeding under the same conditions as that cereal. But it is perhaps of greatest value as a fodder crop for sheep, for when sown early in the autumn, it makes plentiful growth before the end of the year, and by the succeeding February furnishes a good bite for ewes at lambing time. Provided the sheep are not kept on the crop too long, rye re-establishes its growth rapidly and will then produce a good yield of grain. Frequently, however, it is ploughed in after sheeping, and the land left in that condition until it is time to prepare it for roots; on light soils this method of dealing with the crop is an excellent preparation for turnips and swedes.

Preparation of Land and Sowing.—This is in all respects similar to that provided for any of the other cereals. The quantity of seed used is about three bushels per acre which is usually drilled with the ordinary corn-drill. If autumn-sown the crop should be drilled towards the end of September or early in October.

VARIETIES.—There are in reality only two sorts in cultivation in the British Isles—the Winter sort and the Spring sort, of which the former produces the larger quantities of grain. The Spring sort produces a profusion of tillers, but the resulting yield of grain is not very heavy. The yield of grain varies considerably with the sort employed, and with the soil and season, but a good crop is from 3 to 4 quarters per acre.

Rye straw is long, fine and resilient; it has a low fodder value and is consequently usually used for thatching and for similar purposes on the farm. The finest qualities of rye straw, however, may be utilized in making straw hats, etc.

Being hardy and fairly early in ripening, rye is a valuable component of silage mixtures.

Potato.—Although some doubt may exist as to the exact date of the introduction of the potato into this country, there is abundant historical evidence that it was known here towards the close of the sixteenth century. It was cultivated in Chile and Peru for hundreds of years before it was grown in Europe, and the date of its introduction to this continent synchronizes with the activities of the Spanish discoverers and conquerers of that portion of South America. We are probably indebted to the same agency for the initial distribution of the potato in North America and in Europe.

Two sixteenth century potatoes have been described, one in Gerard's Herbal, 1597, and the other by Clusius (Rariorum Plantaram Historia, 1601). Gerard's potato was a white-skinned, round type, while Clusius' was reddish-purple and long.

The potato is most generally propagated vegetatively by means of a tuber or swollen underground stem, and under these conditions the character of the original plant may be reproduced, without alteration, for a long series of generations. Sometimes, however, large changes capable of transmission do occur in one or more portions of the plant and may give rise to a new variety. This, although a rare occurrence, must be regarded as one of the means by which new varieties have arisen.

Many varieties of potato are capable of forming true seed, and the potato flower, although self-fertile, is capable also of being fertilized by pollen of other varieties. In practice it is found that whether self- or cross-fertilized the seedlings produced from the large number of seeds of even a single potato apple exhibit an extraordinary diversity.

It is very probable that in time Gerard's form of potato became crossed with that of Clusius, and the progeny gave rise to the many varieties that were cultivated in the seventeenth and early part of the eighteenth century.

Finally, new blood was introduced from America by the descendants of a self-fertilized potato imported from Chile by Goodrich known as Rough Purple Chile.

To Paterson of Dundee (1810-1870) we owe the Victoria potato from which Magnum Bonum and Champion arose, probably by

crossing with other varieties. In 1845-1847 a series of attacks of potato blight (*Phytophthora infestans*) (p. 369) swept over the British Isles and the Continent with disastrous results, particularly in Ireland, where a large proportion of the population was engaged in agriculture and dependant to a great extent for their means of sustenance on the potato crop.

This epidemic visitation over such wide areas acted as an incentive to efforts to secure a disease-resistant variety, and although none wholly of this character has been produced, many, amongst which Champion was noteworthy, exhibited some degree of resistance, at least for a time (p. 163).

In more recent times, wart disease (*Synchytrium endobioticum*) has been a serious trouble to the potato grower, but in this case, fortunately, some varieties exhibit complete resistance to the disease (p. 366).

The whole history of the potato in this and other countries is a long story of struggle with various diseases, with the result that in any account of agricultural varieties of this plant resistance to one or other malady has necessarily become an important feature of differentiation.

It is not proposed to attempt a botanical classification of the many varieties now in use, here, but rather to indicate those particular characters on which their economic value is based. The first division is generally made on physiological characters such as earliness or lateness in arriving at maturity, and grouping in four divisions is usually considered necessary :—

(1) First Earlies.
(2) Second Earlies.
(3) Maincrop varieties.
(4) Late varieties.

First Earlies.—These usually have colourless skins, and many of them are yellow-fleshed. They are not heavy croppers, but as they are grown with the hope of securing the early market, the enhanced prices then obtained usually compensate for the small yield, and frequently provide the grower with a substantial profit.

The best Earlies are Epicure (r)*, May Queen (k)*, Arran Crest (r), Ninety-fold (k) and Duke of York (k), none of which is immune to wart disease, and Di Vernon (k) which is immune.

As First Earlies are usually dug before any serious visitation of potato blight, the necessity for differentiation into varieties resistant and susceptible to this disease does not arise.

Second Earlies.—Varieties in this section are heavier croppers than those found in the First Early division and the flesh is white, more floury, and less close-textured. The chief varieties here are British Queen (r), Eclipse (k), Sharpe's Express, Boston Kidney (k), Ally (r), Royal Kidney (k), Great Scot (r). Of these Boston Kidney Ally and Great Scot are immune to wart disease.

* (r) [illegible] rounded and (k) kidney shaped tubers.

MAINCROP VARIETIES.—The First and Second Early groups include varieties which by their very nature are habituated to more or less specialized conditions of soil and climate, or to both. The Maincrop group includes the most widely distributed and at the same time the most extensively grown varieties, which are all later in arriving at maturity and heavier croppers than any previously mentioned, and are, in the main, characterized by good quality. King Edward, although susceptible to wart disease, is still the most popular of them all. It is a good kidney shape with shallow eyes *around which there is a characteristic red patch.* It cooks well *and does not blacken quickly after cooking, a feature that commends its use in hotels and restaurants.* King Edward suits good, deep soils and responds well to intensive manuring.

Majestic is another kidney-shaped variety, and is immune to wart disease. It does not produce the good quality of King Edward, but finds a ready market in the chip-potato trade.

Up-to-date (oval), although susceptible to wart disease, is a variety of excellent quality and high-yielding propensities. It was extremely popular in England for a number of years and is still grown somewhat extensively in Northern Ireland.

Arran Chief is a white-skinned, oval variety of excellent quality. Unfortunately it is susceptible to wart disease and also, more than ordinarily susceptible to blight.

Kerr's Pink (r) is a distinctly late variety, but a heavy cropper of excellent quality. It is immune to wart disease, and not very susceptible to blight. On the other hand it has a coloured skin and deep eyes, and both these features operate against its ready sale in the market. It is a heavy cropper and succeeds relatively better than other varieties on inferior soils.

Golden Wonder (long) is another late, wart-immune variety, but somewhat inferior in yielding capacity. This is equalized to some extent by its excellent quality.

SOILS.—Potatoes can be grown successfully on a variety of soils. Large areas of the crop are found, for instance, on warp soils and on Fen land, but when quality, ease in cultivation, and facility in harvesting are considered, the best soils appear to be those containing a fairly high proportion of sand. The potato is definitely a plant requiring a good deal of moisture to produce full and healthy development, but it also demands an open condition of the soil for free tuber development, hence, heavy clays are generally unsuitable, more particularly in districts of heavy rainfall.

The character of the soil exercises a marked influence on the quality of the crop, and although the physical condition of Fen land and similar soils is excellent for growing the crop, the quality of the produce is not generally so good as that obtained on more sandy soils, such as the warps, the red soils of Dunbar, and certain areas in the North of Ireland.

Potatoes do not appear to demand alkaline soil conditions and will, indeed, grow well in soils which are slightly acid.

MANURING.—Potatoes succeed well after a leguminous crop, and consequently often succeed peas, less frequently beans, and commonly clover, in the crop rotation. In some potato-growing districts a one-year clover ley with a very small amount of rye-grass is grown, largely as a preparation for potatoes. The first crop of clover is made into hay and the aftermath left until it is sufficiently grown in the autumn and then ploughed in.

Potatoes do not demand the large quantities of farm-yard manure that can be utilized to such marked advantage with swedes, turnips and mangolds. Farm-yard manure, like other forms of organic material such as mustard, ploughed in, appears to act in the capacity of a soil conditioner with this crop. For this reason many potato growers apply such farm-yard manure as may be used, in the autumn, thereby securing thorough admixture with the soil and the full benefit of the physical effect before the crop is planted.

Farm-yard manure is usually supplemented with dressings of artificial fertilizers, to which potatoes make a large response, even on soils which are in a high state of fertility. Mixtures containing sulphate of ammonia, superphosphate, and potash are usually used, but the quantities applied vary greatly with the class of soil. Much greater use is made of potash with this than with any other farm crop, and because of its influence on the quality of the tuber, sulphate of potash is definitely preferred to other potassic manures, but particularly to the muriate of potash and kainit. Phosphates also play an important part in the mixture, a common example of which is :—

1—2 cwt. sulphate of ammonia
4—6 cwt. superphosphate
2—3 cwt. sulphate of potash

Artificial manures of all descriptions are best applied in the drill immediately before planting.

SEED.—The potato "seed" is not a seed in the botanical sense, but an underground swollen stem, or tuber.

For many years past it has been customary for potato growers in the more southern parts of the British Isles (and the same applies to the Continent) to obtain their "seed" from northern districts—and, it was assumed, the farther north the better. Sometimes after one, more often after two, and frequently after three years' growth in the south, the produce of the imported seed exhibits progressive degeneration until finally, in extreme cases, the plants die away without forming any tubers.

In recent years this degeneration has been the object of a great deal of research, as a result of which it has been shown that the cause of the trouble is a virus (p. 403) Virus diseases occur in a large number of cultivated plants, such as the tomato, raspberry, tobacco, sugar-cane, etc., and their exact nature is still undefined. They are known by their effects rather than by their physical properties. A very important feature, however, is that they can

be communicated from plant to plant by insects. In the case of the potato, if the virus passes from the leaf down the stem into the tuber, the plant eventually arising from such a tuber will contain the virus and its tubers in turn will also contain it, most probably in an intensified form. The effect of the virus diseases is a general decrease in the vitality of the plant, exhibited in the form of lessened vegetative development and therefore of tuber production. The degeneration may be extraordinarily rapid and once started cannot be arrested by improved cultivation or manurial treatment.

Amongst the insects capable of transmitting the virus from plant to plant are the green fly and the jassids, both of which are very common in the more southerly parts of England, but are progressively less numerous as one proceeds from south to north. Thus it is that seed from the north is usually healthier and produces better crops, at least until it becomes badly infected with virus. But the mere fact that the seed originates in the north is no guarantee of its freedom from disease, for this depends first on the initial cleanness of the stock, and then on the extent to which it has been subject to infection. These conditions rather than geographical boundaries demark good from bad seed, and provided the initial stock from which a bulk of seed is produced is virus-free, excellent stock can be raised in Northern Ireland and in high-lying districts in the north of England.

Steps are now being taken to raise virus-free seed on an adequate scale under conditions which expose it to the minimum amount of insect attack.

Some recent work has also shown that resistance of a variety to blight (*Phytophthora infestans*) is reduced when the plant is suffering from virus disease—a finding that accounts in a large measure for the general reduction of resistance to blight exhibited by Champion, for until recently it was extremely difficult to obtain any stocks of that variety which did not exhibit evidence of virus in some form or other.

These considerations rather than any questions of size, etc., determine the value of potato seed, and as the seed tubers themselves bear no manifestation of virus the grower is largely dependent in this, as in many other seed questions, on the veracity of the seed supplier.

Mangolds.—Mangolds were not introduced into this country until some time after turnips had become a recognized farm crop. They are a crop that responds to conditions of high soil fertility and to higher general mean temperatures than turnips and swedes of all descriptions; consequently it is not surprising to find the areas of most intensive cultivation in the east and south-east of England. They are rarely met with in Scotland and are cultivated to a very small extent in Northern Ireland, although they are a much more common crop in the Irish Free State.

Mangolds belong to the genus Beta of the Natural Order Chenopodiaceæ, a great many representatives of which are met

with near the sea and on the littoral of salt lakes. Like the turnips, they are biennials and the root (in this case the hypocotyl and root together), the economically valuable portion of the crop, is produced in the first year. Consequently, except where seed production is the object, the mangold is grown as an annual.

The valuable feature of the crop is the dry matter contained in the root, which varies with the class of mangold from 10 to 14 per cent. This, it will be noted, is not higher than the amount frequently obtained in swedes, but on the average exceeds that produced by white and yellow turnips. Concurrently with this feature there is the fact that the weight of mangolds produced per acre is greatly superior to that obtained from turnips.

Mangolds are usually grouped according to the shape of the root and the colour of the flesh in the following manner :

(1) Yellow Globes, with yellow skin and white or yellow flesh.
(2) Intermediates—a definition referring to the shape of root, which is intermediate between the Globe and the Long. In this class the flesh may be yellow or white and the skin red or yellow.
(3) Tankard.—Skin orange-yellow or crimson and the flesh yellow or crimson.
(4) Long.—Skin yellow or red and the flesh the same colours.

The choice of the variety of mangold for any particular condition is determined by several considerations, chief amongst which are (*a*) the adaptability of the variety to the soil, the various types available exhibiting considerable differences in this respect ; (*b*) the yield of roots and the percentage of dry matter which together produce the important criterion of value, namely, weight of dry matter per acre ; (*c*) the facility with which the roots can be lifted ; and, to a somewhat smaller extent, (*d*) the keeping quality of the roots. Considered in the light of these features the white-fleshed forms of the Yellow Globes and the Tankards are suited to good soils, whilst Long Reds require deep soils and are well-suited to those such as peats, which contain a high proportion of organic matter. The Long forms and, to a less degree, the Intermediates are more difficult to lift than the Globes because a greater proportion of root is actually in the soil.

In point of yield of roots the white-fleshed Globes and the Long Red forms usually produce the greatest weight per acre, and the Globe forms the smallest ; the Intermediate yellow-fleshed forms come next to the Long Reds, whilst the Tankards are relatively small croppers.

In point of dry-matter content, however, the white-fleshed Globes are distinctly inferior to all other sorts, but the yellow-fleshed Globes in company with Tankards and Long Reds are amongst the best in this respect.

When the yield of roots and the percentages of dry matter are combined into yield of dry matter per acre, the Long Reds and

yellow-fleshed Globes are the superior forms and the white-fleshed Globes and the Tankards the least good.

In keeping quality Long Red and Tankard forms are slightly superior to the others.

Position in Rotation.—As a root crop mangolds fall naturally into the root shift of the rotation, and thus usually follow and are succeeded by a cereal. Clean land is essential to the successful cultivation of this crop and if a stubble is foul with weeds every opportunity of autumn cultivation should be availed of, for too frequent movement of the soil in spring may rob the soil of the moisture necessary to secure full germination and a strong " plant."

The crop is sown from the early part of April to the end of May in drills or on the flat, the former method of drilling permitting of more thorough cleaning during growth. The second method of sowing is common in districts of low rainfall, since the soil moisture is better preserved than in the open drills, but it does not permit of the same thorough cleaning and cultivation.

Manurial Requirements.—Mangolds, like turnips, require an abundant supply of lime in the soil to produce normal, healthy development and no fertilizers, whatever their nature, will compensate for or minimize the effects arising from a deficiency in this respect. They are a crop that responds to nitrogenous manures, whether in an organic or inorganic form, but as in all other cases, the full benefit of any form of the three essential plant foods—nitrogen, phosphate and potash—can be secured only when the other two are also present. Phosphates in some readily available form are usually found to give a profitable return, and common salt is frequently a most profitable addition to a mixture, but if it cannot be obtained kainit, which contains a substantial quantity of common salt, may be substituted.

The character of the artificial fertilizers used is largely determined by the lime content of the soil. A suitable mixture for land sufficiently supplied with lime is :—

Farmyard manure ...	up to 20 tons.
Sulphate of ammonia ...	½ to 1 cwt.
Superphosphate	from 2 cwt. on light land to 4 cwt. on heavy land.
Kainit	4 to 5 cwt. on light land, but half the quantity on heavy land.
Common salt	3 cwt.

while for a soil deficient in lime, nitrate of lime or calcium cyanamide may be substituted for sulphate of ammonia and steamed bone flour, basic superphosphate or basic slag may be used in place of superphosphate. The basic slag, however, is slow in action and should be applied to the land some weeks before the seed is drilled.

In addition to these manures, which should be applied in the drill together with the dung before the drills are split just before sowing, 1 to 2 cwt. of nitrate of soda on soils containing sufficient lime or the same quantity of nitrate of lime on those deficient in lime are applied to the crop after singling.

Sugar Beet (*Beta vulgaris*) is a member of a species of the Order Chenopodiaceæ, which includes the mangold, common garden beet and the leafy beet or chard, all of which are regarded as having originated from the wild sea beet, *Beta maritima*.

The wild beet is found in its normal habitat along some of the more southerly European coasts. There it develops a fine slender root and may be an annual, biennial or perennial. Contrary to general belief, individual roots of this species may contain more than 14 per cent. of sugar.

As an agricultural crop sugar beet has been known on the Continent, particularly in France and Germany, for one hundred and fifty years, but its cultivation in the British Isles on an extensive scale commenced about 1920 only. In that year there were 3,000 acres, but the increase in the acreage has been so rapid that there were well over 300,000 acres in 1930, a hundred-fold increase in the space of ten years.

The value of the sugar beet crop depends primarily on the amount of sugar that can be extracted from the root. The percentage of sugar in the root is subject to considerable seasonal variation, to variations due to the character of the soil, and finally to the variety itself.

As the value of the crop to the grower depends on the total quantity of sugar produced per acre, the percentage of sugar is not the only criterion of value, for the same total quantity of sugar may be secured from a small yield of roots with a high percentage of sugar as from a high yield of roots with a lower percentage of sugar.

Sugar beet is a white-skinned biennial producing a large more or less conical-shaped root capable of penetrating the soil to a depth of 12—15 in. The leaves and inflorescence are very like those of the mangold. The flowers are green and insignificant and mainly wind-fertilized. The plant may "bolt" or send up its flowering stem in the first year. The tendency to do this is hereditary and some strains are much more liable to it than others. In all strains, however, too early sowing or a severe check during early growth are conditions which pre-dispose to "bolting."

Provided there is sufficient lime present and that they are deep enough, there are few soils which will not grow sugar beet. The suitability of any particular soil, however, is determined largely by various economic aspects : light soils on the whole are desirable by reason of ease in working them, in lifting the crop, and because the roots are comparatively free of soil when lifted. On the other hand, the yield from such soils is likely to be poor in years of low rainfall unless a probable deficiency in this respect can be met by the liberal use of farmyard or other organic manures.

If it is possible to secure a good seed-bed, sugar beet can be grown on heavy land, but here the difficulty experienced so frequently in lifting the crop and of carting it off the land, together with the impossibility of securing it without an undue quantity of soil are serious limitations.

On the whole when yield and quality and ease in working and lifting are considered together, warplands and medium soils are the most desirable for this crop. Much of the Fenland will produce good yields of beet, but its quality is not high.

Varieties :—The main efforts at improving the sugar beet crop have been directed to the production of the largest possible quantity of sugar per acre, and to a very large extent this has been accomplished by gradually raising the percentage of sugar in the roots. That there must be a natural limit to advance in this direction is obvious, but it is equally certain that progress is still possible by combining high percentage of sugar with high yield of roots per acre, and modern improvement has taken this direction. Combined with these two desirable features attempts have been made to secure such modification in the conformation of the root itself as will render the crop easier to lift. Branching and fanged roots have accordingly been eliminated gradually, and in the best varieties the root is now cone-shaped. Further but smaller modifications are the small-leaved tops and non-bolting strains.

The seed of the varieties in use in the British Isles is at present derived mainly from foreign sources. For purposes of comparison the varieties are divided into three types—E, Z and N. The E types are those producing large crops and not particularly high sugar content ; the Z types are those of decidedly high sugar content, and the N types represent what may be regarded as a combination of the characteristics of E and Z types.

A series of comparative tests was carried out by the National Institute of Agricultural Botany from 1927 to 1929 and in these Kleinwanzleben E produced the largest quantity of sugar per acre and gave the highest gross monetary return.

On the average of three seasons' trials at three centres Kleinwanzleben E produced 13 tons per acre of washed beets containing an average sugar content of 17·3 per cent. and a general average gross value of £33 per acre.

In the same period and at the same centres the lowest weight of washed beets of eleven varieties was produced by Janasz—a Polish sort which gave approximately 10 tons per acre with an average sugar content of 19 per cent. Despite the high percentage of sugar the gross money value per acre fell to £28 5s.

Turnips.—Although turnips, in common with all other tillage crops, have declined seriously in acreage during the past fifty years, they are still the most important root crop in Great Britain. They are at the same time the most widely distributed of the fodder crops and on an acreage basis stand in the same position towards other root crops as oats do towards wheat and barley.

Turnips were grown as a garden crop in this country three or four centuries ago, but did not become established as an agricultural crop until early in the 18th century. In the Low Countries they were an important farm crop for many years previous to their adoption as such in England, despite the enthusiastic advocacy

of Sir Richard Weston, who took the opportunity occasioned by his residence on the Continent (about 1644) to study the systems of cultivation and methods of utilizing this and other crop plants.

It is to Lord Townshend, however, that the extended cultivation of turnips in this country is primarily due. He studied the subject with infective enthusiasm and the value of the roots for cattle feeding was demonstrated by great improvement in his stock, and then as a consequence, in the greatly enhanced returns from his corn crops. By utilizing Tull's turnip drill Townshend was enabled to secure to the turnips the advantage of horse-hoeing, which they had lacked previously owing to being sown broadcast. The value of the new crop for cleaning the land and as a preparation for corn crops soon became widely recognized. Eventually, and as a result of his experiments, Townshend formulated a system of the rotation of crops, subsequently known as the Norfolk four-course, which in its original form was turnips, barley, clover and rye-grass, wheat.

Swede turnips, which are distinguished from the ordinary turnip by the extended stem (generally called the "neck") from which the leaves arise, are reputed to have been introduced into Britain later in the eighteenth century, and Coke of Holkham is considered to have been the first to grow them on a large scale.

Turnips are usually classified in three groups: white turnips, yellow turnips and swede turnips. One difference between the first two and the third group has been mentioned already; a further differentiation is afforded by the leaves: the first foliage leaves of all three groups are rough, *i.e.*, they are covered with short, fairly stiff hairs, but while those of the first two groups are grass-green, in the case of the swede they tend to a bluish and never to a grass-green colour. Again, the leaves of all varieties in the first two groups retain the character of harshness to the touch in all the later produced foliage, but in the swede the later leaves are smooth and glaucous.

The most important economic difference between turnips and swedes, however, is the amount of dry matter they contain. Turnips are characterized by a high percentage of water, 86 to 93 per cent. being a usual range, while the dry matter varies between 9 and 14 per cent. About two-thirds of this dry matter consists of sugar, and the remainder of protein, fibre and ash. White turnips contain the smallest quantity of dry matter and swedes the largest, whilst yellow turnips occupy an intermediate position in this respect.

Finally, swede turnips have a longer period of growth and are hardier than both of the other two sorts, and can be kept without loss for a longer period before being used.

White turnips are so described because they are white-fleshed, but the outer skin may be white, green, purple or mottled green and purple. These turnips grow very rapidly and when sown early are ready for use in early autumn, the leaves and bulbs being

consumed together. If they happen to be left in the ground and encounter a mild winter they will continue to grow, and a late sown crop may then be consumed in the spring. White turnips can thus be utilized to provide fodder over an extended period and are consequently most useful on sheep farms and for cattle, especially milch cows.

Yellow turnips are yellow-fleshed and contain from 8 to 10 per cent. of dry matter ; with regard to the period at which they can be best used, they are intermediate in value between white turnips and swedes.

Swede turnips may be white or yellow-fleshed, but the latter are the more commonly cultivated. The outer skin of the yellow-fleshed types may be green, purple or bronze, but irrespective of the colour of the skin the percentage of dry matter, usually from 10 to 15 per cent., is higher than that found in the white and yellow turnips. They have a long period of growth and a high degree of adaptability to the cooler, moister conditions of the north and west. Their cultivation under the warmer, drier conditions of the midlands and south is attended with more than what might be considered legitimate risk.

The difficulty of securing the germination and establishment of the young plant is ever present with this crop. Damage resulting from attacks of the flea beetle frequently necessitates a second, and even a third re-sowing. Consequently the choice of soil and the methods of cultivation previous to sowing are governed largely by the necessity of obtaining a fine tilth, and of conserving sufficient moisture to ensure germination at what is frequently a dry time of the year.

Turnips and swedes are grown on soils of almost every description, but because of the greater facility in securing the necessary fine tilth, light soils and medium loams are regarded as the most suitable. Under any circumstances the soils should at least be neutral, for with acid conditions the crop is very liable to suffer from attacks of finger-and-toe (p. 364).

Because of the frequent stirring of the soil necessitated by the operations of bunching and thinning, and of their response to frequent horse-hoeing, and of the small amount of damage they sustain during this operation, turnips act as the cleaning crop in a rotation. They are also valuable as the crop to which farmyard manure may be applied with advantage, and, at the same time, without risk of injury attending the large vegetative development induced by that manure in most crops.

An outstanding feature of turnips and swedes is the manner in which they respond to phosphatic manures, especially to those of a readily soluble form, and no mixture of artificial manures can be regarded as suitable for turnips which does not contain a liberal quantity of some form of phosphatic fertilizer. Thus, although a dressing of, say, 10 tons of farmyard manure may produce a remunerative increase in the crop, the increase obtained from a

further 10 tons is not equal to that resulting from the first dressing. The addition of the relatively small quantity of 4 cwt. of superphosphate to the first 10 tons of farmyard manure will indeed give more satisfactory results than the dressing of 20 tons of farmyard manure.

The following mixtures of artificial manures may be used in conjunction with a moderate dressing of, say, 10 to 15 tons of farmyard manure. As an alkaline, or at least neutral soil is essential for the healthy growth of the crop, provision must be made for this in the character of the artificial mixture. This is on soils deficient in lime usually done by substituting basic slag for superphosphate on heavy soils and steamed bone flour or basic superphosphate for the same manure on lighter soils. The different requirements of heavy and light soils are also provided for as follows :—

(1) *Soils not deficient in lime.*

(a) Heavy Soils ...	½ to ¾ cwt. Sulphate of ammonia. 4—6 cwt. Superphosphate. Small quantity of Muriate of potash.
(b) Light Soils ...	½ to ¾ cwt. Sulphate of ammonia. 3 to 6 cwt. Superphosphate. 2 to 4 cwt. Kainit.

(2) *Soils deficient in lime.*

(a) Heavy Soils ...	½ to ¾ cwt. Nitrate of lime or calcium cyanamide. 5 to 8 cwt. Basic slag. Small quantity of Muriate of potash.
(b) Light Soils ...	½ to ¾ cwt. Nitrate of lime or calcium cyanamide. 2 to 3 cwt. steamed bone flour or basic superphosphate. 2 to 4 cwt. Kainit.

The artificial manures recommended for soils deficient in lime cannot, however, be expected to correct a marked lime deficiency. This is a condition which should be rectified by the application of lime in some form and in quantities varying according to the sourness of the soil, preferably several months before the land is sown with turnips.

The mixtures of artificial manures are all best applied with the farmyard manure, actually on top of it, immediately before the drills are split. Their ready accessibility to the young growing turnip plant is desirable, since they assist in establishing it at a critical stage in its development.

Rape is one of the most valuable forage crops, particularly for the sheep farmer. There is a tendency sometimes to regard rapes as comprising a separate group of the Brassicæ, but a truer botanical classification divides them into turnip-like rapes and swede-like rapes, in accordance with the character of their foliage. Those with the lighter-green, somewhat rough foliage come under *Brassica rapa* (turnip), whereas those with smoother, more glabrous foliage are included under *Brassica Napus* (swede).

Rape is a very leafy, succulent plant growing to a height of two to three feet and is cultivated both as a main crop and as a

catch crop. It is particularly suitable for sheep-feeding, and develops so rapidly that if sown in April it may be folded in August. An average crop of rape will yield 12—15 tons of greenstuff per acre, and weight for weight it is of appreciably higher feeding value than swedes.

The commercial sorts in general use are the Giant and Essex dwarf ; the former being usually regarded as more suitable for poorer and lighter classes of soil and the latter for richer soils.

Sowing is invariably done on the flat and the seed may be drilled or broadcast. The latter is the usual procedure and 10 to 12 lb. of seed are required per acre ; if drilled, 4 or 5 lb. are sufficient. Following broadcasting no further cultivations are necessary and, indeed, the manner of seeding makes such impossible. On account of its large and rapid leaf development, rape will smother weeds most effectively.

As a catch crop succeeding such crops as early potatoes or peas, rape fulfils a useful function. After early potatoes harrowing and rolling are all the operations necessary for the preparation of the seed-bed, but after peas it is necessary usually to plough and then harrow down to obtain the requisite fineness of seed-bed.

Kale, Thousand-headed Kale, Marrow-Stem Kale, Kohl Rabi and Cabbage, although very dissimilar in appearance, are nearly-related botanically and are all included in the cabbage group, *Brassica oleracea*. Whether, as is sometimes stated, the various types included in this group originated in the wild cabbage found on the south coast of England has not been, nor is it likely to be, determined with certainty. But the wild cabbage crosses readily with all the cultivated forms found in the cabbage group, as do these also amongst themselves, and these two facts are nowadays regarded as indicating community of origin.

Of the various races in the cabbage group, the kales are most like the wild forms. The thousand-headed kale is a much-branched plant, growing two, three or more feet in height with numerous plain, uncurled leaves, and can withstand both drought and frost. It is an excellent food for sheep and is usually grown to provide "feed" in the early months of the year.

The crop requires cultivations similar to those given to root crops such as turnips and swedes. After a fine seed-bed has been secured, the seed may be drilled and the young plants thinned as desired. Young plants may also be raised in a prepared seed-bed and then transplanted, say, in August. This method secures them against serious damage by the turnip fly.

Once the plants are established the subsequent cultural operations are similar to those practiced with turnips and swedes—the horse-hoe being kept going until the crop has arrived at a stage when a continuance involves physical damage to the plants.

The principal use of thousand-headed kale is as a green food for ewes and lambs in the early months of the year, but it may be consumed at any other time, and the proposed use of the crop

determines the exact time of sowing or transplanting. When ready for consumption the crop may be folded off or cut and fed to sheep on grass.

Curly kale, which is cultivated and utilized very similarly to thousand-headed kale, is a hardy plant with numerous large leaves which are strong curled owing to a disproportionate growth of the leaf margins.

Kohl Rabi (*Brassica oleracea caulo-rapa*) or the turnip-rooted cabbage, is a crop confined mainly to the eastern and south-eastern counties of England. In this plant the stem immediately above the cotyledons or seed leaves becomes much swollen and bears large scars, the marks of the junctions of earlier leaves with the stem.

In the comparatively dry eastern counties the cultivation of swedes is particularly difficult owing to their liability to mildew if sown early and to attacks of turnip fly if drilled later in the season. In these circumstances kohl rabi provides an excellent substitute, and, moreover, as it does not suffer severely from drought, its cultivation can be extended to lighter soils than those on which it would be possible to grow swedes at any time.

Kohl rabi is cultivated similarly to swedes and turnips except that it is more commonly sown on the flat than on ridges. Early sowing followed by frequent horse-hoeing, both before and after singling, are desirable.

The crop, which makes excellent feeding for both cattle and sheep, varies from 15 to 25 tons per acre. It may be folded off, but it can also be lifted and stored like swedes.

Kohl rabi is much more resistant to frost than swedes or turnips and, if necessary, can be left without lifting much longer than those crops : its keeping qualities are remarkably good.

MARROW-STEM KALE is a comparatively new crop produced by crossing kohl rabi and thousand-headed kale. In this plant the stem is swollen as in kohl rabi, but it is elongated instead of spherical, thus producing a form intermediate between kohl rabi and thousand-headed kale.

Marrow-stem kale is capable of producing very large quantities of greenstuff, which is relished by stock. It will thrive on a wide range of soils, the two main requirements for successful cultivation being a sufficiency of lime and freedom from water-logging. Its principal utility is as a green food for cows in August.

The cultivations for the crop are the same as those adopted for swedes and turnips : the seed may be drilled and the plants thinned and sometimes singled. Alternatively, plants may be raised in a prepared seed-bed and transplanted when ready. If drilled, this should be done as early as possible so as to minimize the risk of damage by the turnip fly. The average yield of marrow-stem kale is 25 to 30 tons per acre, which in actual total feeding value is much in excess of that of an average crop of swedes, whilst the cost of production is comparatively low. The crop effectively checks the growth of weeds.

Cabbage (*Brassica oleracea capitata*).—In the cabbage proper the main stem of the plant is much shortened and the smooth, glaucous leaves are closely folded over each other, thus producing a well-compacted, hard head. In shape, size, colour and hardiness the group furnishes examples of wide differences. Thus, there is the small ox-heart cabbage, the rounder ball-head and the drum-head ; the first, and to a large extent the second, by reason of their more tender and better flavoured leaves, are used mainly for culinary purposes, whilst the drum-heads provide a valuable green food for stock.

In colour cabbages vary from green of various shades to red or purple and in hardiness from some forms which can be grown in summer only to those, like Savoy, which are capable of withstanding fairly severe winter conditions.

Recently a tendency to cultivate early cabbages has developed in the neighbourhood of towns. For this purpose seeds are sown in prepared beds in August and the young plants are transplanted in October. Unless the winter happens to be unusually severe, the crop is ready for marketing in May and early June at a time when, owing to the general scarcity of fresh vegetables, the prices obtained are usually remunerative.

For farm stock, however, the drum-head is the form cultivated and in this case seed is sown in spring and the plants transplanted into land which has been manured and cultivated, in early summer. The crop is then utilized as it becomes available, mainly for milch cows and sheep. Cabbages are said to increase the flow of milk which is not so liable to be tainted as it is when turnips and swedes are fed.

Cabbages, in common with other crops in this group, require liberal manuring to produce the best results. They respond to farmyard manure, and when this is available it may be applied to them in large quantities. Failing this a mixture of artificial fertilizers composed of :—

1½-3 cwt. of sulphate of ammonia,
3-5 cwt. of superphosphate, and
1 cwt. of muriate of potash per acre

may be used. The whole of the sulphate of ammonia may be included with the other two fertilizers in the mixture, which should be applied before transplanting is done, or a portion retained until the plants have begun to grow and then sprinkled in the rows, care being exercised to avoid the manure coming into direct contact with the plants.

Mustard.—There are two species of mustard cultivated in England, namely Brown or Black Mustard (*Brassica nigra* or *Sinapis nigra*) and White Mustard (*Brassica alba* or *Sinapis alba*). Both are annuals and in many respects are nearly related botanically to the cabbage, swede and turnip. All of the latter may be distinguished, however, by their sepals, which are perfectly erect when the flower is open, whereas in the mustards they are widely spreading.

Black Mustard is mainly cultivated for its seed, which contains as much as 22 per cent. of oil and can be extracted under pressure. The seed is also grown for utilization in the manufacture of the table condiment.

The plant grows to a height of from 2 to 4 ft.; the stem is much branched and covered with stiff hairs; the lower leaves are light-green, large, lyrate and rough, but the upper leaves tend to become more lanceolate and smoother. The inflorescence is a raceme with pale-yellow flowers and short smooth fruits with a small slender beak. The fruits, which are very slightly constricted above and below each seed, are closely adpressed to the stem.

The seeds are somewhat oval and brownish-red in colour: both black and white mustard seeds are at least twice the weight of turnip, cabbage and swede seeds.

Black mustard requires good, deep, fertile soil, and is for this reason usually grown on the deep alluvial soils of Lincolnshire, Cambridgeshire, and Huntingdonshire.

It is frequently taken after potatoes, which are generally manured liberally in those localities, but it may follow a corn crop. In such cases a dressing of farmyard manure is necessary; or failing this, 3 to 4 cwt. of superphosphate is often applied.

The crop is sown in February, or more commonly in March, and is ready for harvesting in August. Drilling is done in 15—18 in. rows at the rate of 4—5 lbs. of seed per acre and the plants are thinned out if necessary by running a horse-hoe across the drills. It is usually cut by hand and the exact time of cutting requires to be carefully judged so as to avoid shrivelled unripe seed on the one hand or the shedding of over-ripe seed on the other.

Special care is necessary to avoid loss of seed by shattering during harvesting operations and threshing, which is performed by the ordinary steam tackle. The yield of seed varies from about 10 cwt. to 20 cwt. per acre, but the latter figure is obtained only under the most favourable conditions.

White Mustard is grown largely as a sheep feed or for green manuring; it is a taller and somewhat stronger growing plant than black mustard. The inflorescence and flowers of the two are very similar, but the fruits of white mustard are short and rough with a decided, dagger-shaped beak, and thus differ materially from those of the sister species. The seeds are whitish-yellow in colour and larger than those of black mustard.

White mustard is a quick growing crop and may be sown later than black mustard in consequence; it does not shed its seed quite so readily as that sort and may thus be cut with a self-binder. It is also claimed to be less susceptible than black mustard to damage by the mustard beetle.

Leguminous Crops.—A very important series of agricultural plants are those included in the order Leguminosæ, the flowers of which are described as "papilionaceous" on account of their supposed resemblance to a butterfly. With few exceptions, the

fruit of these plants is a pod or legume. In some cases such as the bean, pea and lentils, which are termed "pulse crops," the plant is cultivated mainly for the seed, although the haulm or straw is capable of being used as fodder, but the greater number of plants are utilized for the production of fodder only.

The clover and pulse crops are particularly valuable products since the leaves in the first and the seeds in the latter case are rich in protein. Beans, for instance, contain double the quantity of protein found in wheat and oats and almost three times the quantity found in barley. This in itself would constitute no particular merit if the protein resulted from the liberal use of nitrogenous manures in some form. The important feature of the crops is rather their ability to make use of the free nitrogen of the air through the medium of certain bacteria which exist on the roots of most Leguminous plants. The centres of operation of these bacteria are the nodular swellings distributed in an irregular manner over the root, which are in fact the result of a rapid proliferation of the tissues of the root and represent an attempt on the part of the plant to resist the progress of the bacteria. Having arrived at this stage both parties to this curious action appear to benefit—one to the extent of obtaining nitrogen in some form from the bacteria, the other by securing the carbohydrates they require for their life processes from the plant.

Clovers.—Clovers are essentially fodder plants and belong to the genus Trifolium, so named in allusion to the leaves, which are made up of three separate leaflets. In this genus the inflorescence is borne on peduncles or flower-stalks, which vary in length in the different species. Each individual flower of the flower head or inflorescence arises on a short stalk or pedicel.

The most important clovers found in general cultivation in the British Isles are :—

Botanical Name.	Common Name.	Colour of flower-head.
Trifolium pratense	Red clover	Red or purple
Trifolium hybridum	Alsike clover	Pink and white
Trifolium repens	White or Dutch clover	White
Trifolium incarnatum	Crimson clover	Crimson
Trifolium minus	Yellow Suckling clover	Yellow

Red Clover.—Of the genus Trifolium this is one of the most important species, at least in alternate husbandry. The plant may be from a few inches to two or more feet high and the stems, which arise from the crown of the plant, may be few or numerous approximately circular in section, hollow or more or less filled with pith, and terminating in an inflorescence. The leaves are trifoliate and each leaflet arises directly from the top of the leaf-stalk (petiole) which is very short and appears at times to be almost entirely absent, in marked contrast to the longer petioles found in white clover, and more especially in alsike. The leaves are stipulate and the stipules are membranous with strongly developed greenish-purple veins. The leaves are usually covered with hairs (pubescent)

along their edges and on their upper and lower surfaces, and almost invariably bear a white marking on the upper surface.

The inflorescence is a spherical or ovoid head composed of a large number of single papilionaceous flowers of a red to slightly purple colour. The fruit is a single-seeded capsule (pyxidium) which opens by an irregular transverse fracture separating the upper from the lower portion.

Red clover is largely insect-fertilized (bee) and the quantity of seed obtained in any season depends, therefore, amongst other conditions, on the weather at flowering time.

The seed, which is the largest of the cultivated clovers, is of a yellow colour shading to purple, the density of which varies with the degree of ripeness of the seed. The plant develops a strong tap-root capable of penetrating to considerable depths.

The history of the origin of red clover, as of so many of the agricultural crops, is obscure, but there are good reasons for thinking that it is not a native of the British Isles. It was the subject of considerable notice in the agricultural literature of the 16th century, especially on the Continent, and there is a strong probability that it was introduced into England from there by Sir Richard Weston, or reached here as a result of his strong advocacy. Its value for stock feeding and as a preparation for wheat, soon became recognized, and it has suffered no diminution of popularity with the progress of time.

It is almost certain that the original stocks contained a large number of strains and the crop as now grown is remarkable for a large number of localized sorts. These differ not so much botanically as in features which are usually regarded as physiological, such as persistence, adaptability to conditions of varying degrees of soil fertility, resistance to disease, rapidity and luxuriance of early growth, and persistence of growth into the autumn. These characteristics, it will be noted, largely determine agricultural values.

Within the last ten years a good deal of attention has been devoted to red clover by the workers at the Welsh Plant Breeding Station and as a result of their investigations the agricultural values of the various strains can now be more accurately assessed than was formerly the case.

For present purposes the various strains in general cultivation may be arranged in three main groups :—

Wild Red Clover (*Trifolium pratense spontaneum*).

Early-flowering Red Clover (*Trifolium pratense præcox*).

Late-flowering Red Clover (*Trifolium pratense serotinum*).

Wild red clover is a perennial plant found naturally in old pastures and is readily distinguished from forms utilized in alternate husbandry by the following features : the stems are few in number and usually more or less prostrate, small, slender and frequently solid, while the leaves are small and dark-green and not very numerous.

The differences between the early-flowering and late-flowering sorts are almost as remarkable as those between them and the wild red. Thus the early-flowering are almost erect in habit of growth, but with shorter, fewer and more hollow stems, but larger leaves. They are truly biennial in character and grow rapidly both in the seeding year and after cutting, they also grow well into the autumn. None of the various strains, of which the following are the best known, is immune to clover sickness : English Broad Red, Vale of Clwyd, Canadian, New Zealand, American, French.

The late-flowering sorts are more spreading in habit of growth, they tiller more abundantly, and the stems are longer, more slender and weaker. As a group they are more productive in exposed positions and on less fertile soils. They are not strictly perennials, although they may remain in active growth for four or five years or occasionally longer. They exhibit a very slow growth in the early portion of the year and the first year's produce is somewhat limited. In subsequent years, however, they produce abundant crops of hay of excellent quality. Their aftermath production, on the other hand, is meagre unless the hay is cut early. Although not immune to clover sickness, the late-flowering sorts are less susceptible than those found in the early-flowering group.

The chief strains are :—English Late, Montgomery, Cornish Marl, Swedish Late, American Mammoth, Norwegian, Danish, Altaswede.

The uses to which the various sorts may be put is clearly indicated by the characteristics outlined above : thus, wild red clover is definitely a meadow or pasture plant ; early-flowering clovers are pre-eminently suitable for use in one-year or at the most two-year leys, but should never be sown on clover-sick land ; the late-flowering forms can be relied upon to last three years at least, they are less susceptible to diseases and may be relied upon to succeed in more exposed positions and generally in less fertile soils.

As a general rule clovers obtained from northern regions are more reliable and more productive than those obtained from farther south, and under conditions in this country crops raised from local strains have proved superior to those obtained from imported seed.

White Clover (*Trifolium repens*). Although, as has just been shown, there are forms of red clover in existence which, by reason of their persistence are useful constituents of permanent mixtures, there is no clover with such unmistakable features of a pasture plant as white clover.

Compared with all the clovers, excepting perhaps yellow suckling, white clover is small in every feature. The numerous stems arising from the crown of the plant are fine, usually solid, with short internodes and a distinctly procumbent habit ; the leaves and flowers arise on fairly long stalks from the nodes from which points adventitious roots also arise. These penetrate

into the soil, thereby securing the stems in position and at the same time performing the other usual functions of roots.

Owing to the horizontal manner of growth of the stems, it naturally follows that the leaves and flower-stalks grow more or less at right angles to them, and it is consequently only these portions of the plant that are eaten by stock or secured on cutting.

The leaves are small and usually hairless and frequently bear a white marking ; the flower stalks are long and the flower heads usually white or pinkish-white, but occasionally a creamy yellow. The fruit is a legume or pod containing one, two or three small, yellow or slightly terra-cotta coloured seeds.

As in the case of red clover, there are, however, amongst the plants which constitute white clover and wild white clover as commonly known and grown, a number of forms differing from one another in such features as the size of the plant and its constituent parts—stems, leaves, flowers and seed, in their rate of growth and extent to which they spread, and more economically important still, in their degree of permanence.

A form of very wide distribution is Dutch or as it was once widely known, honeysuckle clover. It is highly probable that white clover, like red clover, found its way into England from the Low Countries, and the retention of the name of the supposed country of origin affords some justification for this view.

Within recent years considerable attention has been devoted to a form known as wild white clover, which exhibits a higher degree of permanence, a more prostrate and more widely spreading habit of growth than the ordinary white or Dutch clover.

Wild white clover is found as a constituent of old permanent pastures from which a large portion of the seed used in this country is still supplied. It is altogether a smaller plant than the Dutch white clover, but in its permanence, rapid growth, ability to withstand close grazing by stock, and its drought resisting capabilities, it possesses attributes of high economic value. The flowers of wild white clover may be white, cream, pale yellow or slightly pink in colour, whilst the seeds are smaller and more rounded in outline than the ordinary Dutch white with a less distinct groove between the radicle and cotyledons.

As wild white clover is a distinctly perennial herbage plant it has very largely replaced the ordinary white clover as a constituent of permanent grass mixtures. The latter may be depended upon to last from four to five years, and thus because of its somewhat more abundant growth it forms an important constituent of seeds mixtures for short leys. Although all forms of white clover possess a fairly well-developed tap root, they depend largely on the rootlets arising from prostrate, creeping stems to secure their maximum vegetative development. They are in fact largely surface feeders and it is less the character of the soil than the rainfall or general humidity of the air that determines the extent of their development.

Thus, although wild white clover will succeed on heavy, clay soil because the supply of moisture is usually adequate on account of the slow percolation of rain-water, it will also grow well on light, sandy soil, provided there is an adequate supply of moisture to maintain the adventitious roots in full activity. All forms of white clover, however, demand an alkaline condition of soil.

As white clover is usually only one constituent of a seeds mixture, the question of the system of manuring best suited to it must be viewed from more than one standpoint. Thus, nitrogenous manures are not harmful in themselves, but in so far as they encourage the taller-growing species of grasses and so restrict the development of the clover they are, at least, not advantageous. Moreover, so far as the clover itself is concerned, nitrogenous manuring is almost entirely unnecessary. To phosphatic manures white clover exhibits a quick and in many cases a striking response. As already mentioned, clover demands alkaline soil conditions, and for this reason basic slag has produced extraordinarily good results, for it contains a readily soluble form of phosphate together with a large proportion of active lime. Superphosphate is also effective and raw mineral phosphates may also be used with good results if they are finely ground. As a general rule the application of potash manures on heavy soils is unnecessary, but on lighter soils they frequently produce remunerative results.

Owing to its high feeding value white clover has been used extensively for improving poor pastures; its ability to make a thick, close "bottom," thereby minimizing the spread of weeds and preventing undue evaporation of moisture, and by so doing encouraging the growth of grasses, has proved extremely valuable and has certainly enabled a larger head of stock to be fed on the land than was previously possible.

ALSIKE CLOVER (*Trifolium hybridum*) is an upright-growing plant, but much less robust than red clover. The leaves are hairless and borne on fairly long stalks; in shape they approximate to those of white clover, but unlike both red and white clover, they are devoid of any trace of markings on the leaf.

The flower head (inflorescence) is borne on a fairly long stalk; the individual flowers are pinkish-white and the seeds, which are light to dark-green in colour, are only about half the size of red clover, but about half as large again as those of white clover.

Alsike has a relatively short period of growth and for this reason, combined with its upright habit of growth, it is more suitable for hay than for pasturing. It is less susceptible to clover sickness than red clover and thus possesses special value on land subject to that disease. Although no more persistent than red clover, it appears to be better suited to heavy clay soil and to peaty land.

YELLOW SUCKLING CLOVER (*Trifolium minus*) is a small, low-growing, annual plant that maintains a perennial appearance by the facility with which it seeds itself. It has a very limited use

except as a component of mixtures for poor, thin soils devoted to sheep grazing.

Crimson Clover (*Trifolium incarnatum*) is an erect, tall growing, annual clover whose cultivation is confined to the south and south-east of England. The leaves are heavily felted with fairly long, fine hairs which give the plants an almost white appearance when seen in bulk. The inflorescence is elongated and the individual flowers are a striking crimson. There is, however, a white-flowered variety, and of the crimson form there is an early and late variety.

Crimson clover is usually sown in the autumn on corn stubbles which have been lightly cultivated, and is fed off by sheep in the early summer of the following year.

Lucerne (*Medicago sativa*), known as Alfalfa in some countries, is an important leguminous forage plant. It possesses a strongly-developed tap root capable of penetrating into the soil to considerable distances and is consequently able to sustain continued growth in periods of deficient rainfall.

For some time in the early stages of development of the plant growth is confined to the elongation of the main stem, but later secondary branches arise from the axils of the cotyledons and from the lower internodes, and the plant gradually assumes a much more bushy appearance. This becomes more pronounced after two or three years growth, when numerous entirely new stems arise from the stout root stock.

The stem of lucerne is green, erect and succulent ; the leaves are trifoliate : each leaflet is dentate, with a notched tip and the mid-rib projecting into a small point. The middle leaflet is borne on a short petiole. The inflorescence is axillary and racemose and the flowers are usually purple. The fruit is a spirally-coiled dehiscent legume containing several greenish-yellow kidney-shaped seeds.

In some respects lucerne is an exacting crop, for although it will thrive on a fairly wide range of soils, one essential of them all is the presence of sufficient lime to render them alkaline. Again, the soil must be adequately drained, for the slightest water-logging is inimical to the plant. Usually lucerne succeeds best on soils in good heart.

Although lucerne is a most nutritious forage crop, the acreage devoted to it is relatively small and very localized. Thus, more than half the total acreage is found in Essex and a very small acreage in the western counties, a strong indication that the plant is not responsive to heavy rainfall.

Lucerne does not attain full development until two or three seasons after sowing, and as early growth is often meagre, there is a danger of weeds establishing themselves during this period and thereby seriously impeding the further development of the crop. For this reason the seed is often drilled in rows and the plants inter-cultivated so as to check weed growth.

One reason for the slow development of the cultivation of lucerne is the difficulty experienced in obtaining a good " strike," but the introduction of a simple method of inoculating the seed with the bacteria usually found in the root nodules of well-grown plants, has very materially improved matters. The cost of inoculation is very small : consequently no one proposing to grow lucerne should take the risk of even partial failure with its attendant condition of foul land.

Lucerne is utilized in several ways : it may be cut and fed green, as a soiling crop or it may be made into ensilage. It also makes excellent hay, provided too much leafage is not lost in the process, and as three cuts are frequently obtained from a well-established crop, it is not unusual to secure two hay crops in a season.

When once established, lucerne may be severely cultivated without sustaining injury : indeed repeated cultivations frequently benefit the crop in addition to assisting in keeping the land clean.

The seed of lucerne is obtained to a somewhat limited extent from English-grown crops, but the greater part of the seed used in this country is obtained from foreign sources. The most common strains are Provence, Hungarian and Grimm. Some tests conducted by the National Institute of Agricultural Botany at Long Sutton, Hampshire, in 1925—30 indicated the superiority of Hungarian seed with Provence seed second best and Grimm and English seed approximately equal at third place. English seed is usually regarded as superior for British conditions, but the small quantities grown make it expensive and it is not infrequently low in germination. Such, indeed, was the case in the particular tests alluded to; but despite this the total yield obtained from the English seed during a period of six seasons was 92 per cent. of the control Provence.

After a successful crop of lucerne the soil is enriched to such an extent by the decay of the stems and roots that corn crops, if sown immediately afterwards, invariably lodge badly. For this reason it is customary to follow lucerne with a root crop, frequently potatoes.

Trefoil (*Medicago lupulina*), known also as Black Medick, Yellow Trefoil, Hop Trefoil, is an annual or at times a biennial, found in abundance on chalk and other soils containing an abundance of lime. The root, which does not produce many secondary branches, penetrates the soil to a depth of about a foot. The stem branches, which may be from a few inches to about two feet in length, arise from the crown of the root ; they are slightly angular and covered with very short hairs. For a short portion of its length the stem lies horizontally and then rises into the air and becomes somewhat branching.

The leaves are small, trifoliate, and in each leaflet the mid-rib projects beyond the margin of the leaf into a small point ; the middle leaflet is borne on a short petiole.

The inflorescence is carried on a somewhat short, axillary peduncle and the flowers which are massed closely together in a head, are small, papilionaceous and bright yellow. The fruit is a small, black, indehiscent pod curved on itself and contains a single greenish-yellow seed compressed laterally and so resembling a broad bean in shape.

The inflorescences of trefoil and yellow clover are sometimes confused, but the persistance of the calyx of the latter is a ready means of differentiation.

Although trefoil does not contribute greatly to the bulk of material obtained in seeds mixtures, it is nevertheless frequently included in small quantities in pasture mixtures intended for calcareous soils, for it produces an early and nutritious " bite " for sheep. It also seeds itself readily and consequently almost functions as a perennial.

Trefoil is unsuitable for hay mixtures and will not grow on soils deficient in lime ; it is claimed that it withstands cold weather better than red clover.

Sainfoin (*Onobrychis sativa*), another leguminous plant, occupies an important position both as a hay and a pasture crop, more particularly in the eastern and southern counties of England. From the fact of its localization in these parts, sainfoin is commonly but erroneously regarded as a plant suited to the shallow, dry soils of the chalk and limestone formations only. It can, however, be grown successfully on a wider range of soils, provided they are well supplied with lime, adequately drained, and possess a low water-table. Under these conditions the crop can be utilized as far north as the Humber and as far west as the Severn.

The stem of sainfoin is strong, erect, and succulent, solid in the upper portion and becoming more or less hollow towards the base. In early growth there is only one stem, but this is supplemented in a very short time by a succession of additional stems arising in a more or less regular manner from the crown of the plant. The leaves are pinnate and the leaf stalk terminates in a leaflet. The flowers are a bright rose, arranged in a racemose inflorescence, and when in full bloom are a striking feature of the crop.

The root is long and strongly developed and capable of penetrating to considerable depths in suitable soils, and is consequently able to maintain uninterrupted growth through extended periods of drought.

The pods or true fruits are broad and flattish, straight along one edge and curved along the other, which bears a few strongly developed teeth, and thus give the fruit a cockscomb appearance. The surfaces of the two sides of the pod, or, as it is very generally known, the " cosh," are raised in a coarse network which sometimes bears a number of fine teeth ; the pod contains one light to dark-brown, kidney-shaped seed which is six or seven times the weight of a lucerne seed.

Sainfoin is essentially a forage plant and may be included in "seeds" mixtures with red and crimson clover, but it is most successful and consequently most commonly grown as a pure crop. When sainfoin is sown with a cereal, barley is usually the "nurse-crop" on light land, and wheat on heavy land. In the former case, and especially in dry districts, it is usual to drill the sainfoin at the same time as the barley, but at right angles to the rows of that crop. As with the other smaller seeded leguminous crops a firm seed-bed and a fine tilth are essential.

Sainfoin, like lucerne, makes hay of high feeding value, but it possesses the additional value of furnishing excellent pasturage for all classes of live stock, and this, owing to its drought-resisting capabilities, frequently at a time when ordinary pastures are in a low state of production.

There are two commercial varieties in general use : the common sainfoin, and the giant or double cut sainfoin, which are similar in appearance. The giant sainfoin, however, is best suited to light soils, where it is grown for one or two years, but more often for one year only. In this case the first cut is usually made into hay and the second either saved for seed or folded with sheep.

Common sainfoin is a more permanent form than giant sainfoin and is better suited to medium rather than really light soils. If the serious invasion of weeds can be prevented, common sainfoin may be left down for five to seven years, or even longer.

From giant sainfoin the average yield of hay is about 30 cwt. per acre, whilst after the second year yields of double that amount may be obtained from common sainfoin.

Vetch.—Plants of the forms of the vetch most commonly grown in the British Isles are characterized by fine, square, trailing stems, frequently six or more feet in length ; the leaves are pinnate with numerous obovate leaflets, and the leaf stalk usually terminates in a simple or branched tendril. The flowers arise either singly or in pairs on short stalks, or as racemes, in the axils of the leaves ; the colour of the flowers is blue or purple ; white, yellow and scarlet flowers occur in the less commonly grown forms.

The vetch is widely spread in temperate climates and some authorities have described twelve species, but only three are met with commonly in the British Isles :—

The Common Vetch (*Vicia sativa*).
The Tufted Vetch (*Vicia Cracca*).
The Hairy Vetch (*Vicia villosa*).

Of these the tufted vetch (*Vicia Cracca*) is a perennial, while the other two are annuals or, occasionally, biennials.

Agriculturally, apart from the production of seed, vetches are used as an ingredient of forage and silage mixtures, for folding, or for making into hay and have little or no use as pasture plants. In all these cases oats, beans or wheat, but most generally the two former, are included with the vetches, as their stronger and more erect stems furnish a support to which the weaker trailing

vetch plants may attach themselves. It is thus largely on differences in the ability to withstand cold and other winter conditions, on the quantity of green material produced, and on the length of time occupied in attaining full vegetative development that the annual species are compared.

In the British Isles the best known and most widely-used form is the common vetch (*Vicia sativa*), of which there are spring and winter sorts, which although similar botanically differ in their ability to survive the winter. Both these sorts are distinguished readily from other species by their flowers which are reddish-purple and occur singly or in pairs on short stalks arising in the axils of the leaves.

Goar vetch, or summer vetch, which is grown extensively in some districts, resembles the common vetch in its flower characters, but it is a stronger growing plant with larger leaves, stems, and pods than that sort. The Goar is apparently as hardy as the common vetch, but arrives at full growth somewhat earlier. By sowing portions of the land devoted to vetches with the common vetch and the remainder with Goar, the period of gathering a silage crop may thus be extended without incurring loss in the nutritive value of the silage due to over ripening and the attendant development of fibre.

The seed of Goar vetch is dark brown to a leaden colour with undermarkings of black; in its flattened shape it resembles the common vetch, but it is considerably larger, almost approximating to the size of a small pea.

The hairy vetch (*Vicia villosa*) is a longer, finer and more hairy plant than the common vetch; the inflorescence is racemose and the flowers are numerous and a deep blue colour. It is claimed that this vetch is hardier than the common vetch, but the leaves are smaller, and for silage requirements it does not appear to possess any marked advantage. The seeds are almost spherical and much smaller than the common vetch, and dark velvety-blue or almost black in colour.

Vetches do not exhibit a strong partiality to any particular class of soil; they may be grown on stiff clays, if adequately drained, and equally well on sandy soils, provided the supply of moisture is sufficient. Like most leguminous crops, however, they demand a plentiful supply of lime in the soil. In their ability to thrive on poor soils they furnish the occupier of that class of land with a valuable means of increasing the stock-carrying capacity of his farm.

Utilization of Vetches.—Vetches may be utilized in several ways; they may form a constituent of silage mixtures or be grown for folding and soiling, or they may be made into vetch hay; lastly, they may be cultivated for seed production.

They do not occupy a regular position in the crop rotation, but as a pure crop it is a widely followed practice to sow them after a cereal. In this case the land is sometimes ploughed and the

seed then drilled at the rate of 2¼ bushels (approximately 11¼ stones) per acre from September onwards. Provided they are sufficiently well covered to prevent depredation by birds, it is inadvisable to bury the seed too deeply; about one inch is the ideal depth. As with all crops intended for hay, the most suitable time for cutting is whilst the plant is flowering and before it has started to set seed.

When grown for soiling, silage or folding, it is customary to include oats, rye or beans with the vetches as these plants provide a support for the trailing vetches, and by so doing obviate the waste which is liable to occur, particularly in wet weather, by the plants lying on the surface of the soil. Winter oats should be used with winter vetches, and a mixture of 1½ bushels of oats with 1½ bushels of vetches is a useful seeding.

In some cases vetches are sown on stubbles which are merely cultivated and harrowed until a sufficient tilth is secured, and the land harrowed again to cover the seed, a practice that can only be recommended when the stubbles are reasonably clean.

In addition to the several means of utilization described above, in districts possessing a suitable climate vetches are made into hay, but they require a long period of dry weather to cure the succulent stems and may suffer considerable damage if subjected to heavy rain. When intended for hay the crop should be cut when still in flower, for concomitantly with the development of the seed the stem becomes more fibrous, and consequently less valuable for feeding. The yield of hay varies from 1½—3 tons per acre.

When grown for seed production, vetches are sometimes sown as a pure crop, but a more satisfactory method is to include a small quantity of beans as a support for the vetches, and thus obviate wastage. The bean seeds may be readily separated from the vetch seed by riddling after thrashing. The yield of seed may be as much as 30 bushels, but is subject to wide variations and an average figure is nearer 20 bushels per acre.

MANURING.—When the crop is grown for seed, nitrogenous manures should be used sparingly, if at all, for they over-stimulate the production of haulm. The same objection does not apply in the case of crops intended for soiling or for silage. Nevertheless, the necessity for the application of nitrogenous fertilizers does not exist with this, in common with other leguminous crops, to the same extent as it does with crops which are unable to utilize the free nitrogen of the air.

On heavy soils phosphatic manures such as basic slag at the rate of 3—6 cwt. per acre, and superphosphate at the rate of 2—4 cwt. per acre, frequently prove beneficial, and in some cases, particularly on lighter soils, these may be supplemented with potassic fertilizers such as muriate of potash, 1 cwt. per acre or kainit, 3 cwt. per acre.

A further important group of agricultural plants belonging to the Leguminosæ are the peas and beans, commonly described as

pulse crops. In the pulse crops, although the stem of the plants may be utilized as fodder, the primarily important portion of the plant is the seed, which by reason of its high protein content forms a valuable food for stock.

Beans.—The bean plant is distinguished from the clovers, vetches and peas principally by its square, upright, hollow stem, which varies with the variety from a few inches to several feet in length. The leaves are pinnate, and usually consist of two, four or six leaflets, but the petiole or stalk of the leaf instead of terminating in a tendril, as in vetches and peas, ends in a short, very much reduced leaflet. The flowers arise as short racemes in the axils of the leaves.

Up to the time of ripening the pods are soft and green, with a soft, woolly lining. On ripening they dry up considerably, become black and much tougher, the soft lining disappears, and if left until completely dry the pods eventually split along both the upper and the lower lines of division, and the seeds are ejected violently.

The bean is characterized by a strongly developed tap-root which is capable of penetrating to considerable depths and eventually when ploughed in of adding large amounts of organic matter to the soil.

In addition to the varieties commonly designated "field" beans, there are many varieties cultivated as vegetables for human consumption. These are botanically similar to the field bean, but differ therefrom mainly in the greater length of the pods and in the shape of the seeds, which are broader and flatter. Many of the garden kinds are described by some qualification such as "Longpod" or "Broad" Windsor, terms descriptive of the pods and seeds.

Of the beans used in field culture, there are a great many sorts, and winter and spring habits are a useful initial means of differentiation. Winter beans, as a whole, exhibit as a first requisite a certain degree of winter-hardiness, and when sown under comparable conditions do not display the same rate of stem growth as the spring forms. Again, the winter forms develop more secondary stems and usually produce crops with a fuller growth than spring sorts and are better able consequently to minimize the activity of weeds.

The spring forms exhibit a greater distance between the points of origin of the leaves on the stem, and although usually sown several weeks after the winter sorts, they come into flower at approximately the same time.

Amongst both winter and spring sorts there is wide variation in the size, shape, and colour of the seeds, but they are all smaller, less broad and more rounded in section than the culinary varieties. The different sorts are found under such names as English horse bean, Scotch horse bean, and others, again, are described by the

name of the locality from which they were obtained. Despite this attempt at differentiation, the average crop, irrespective of name and origin, consists of a large number of different forms. By selection and individual culture these may be maintained reasonably pure for some time, but there is always some cross-pollination by bees and through other agencies, which operates against varietal purity.

Amongst the spring forms the tick bean at least deserves some notice. This is a sort characterized by small, distinctly rounded seed, which in some years is almost circular in section. It is grown extensively in the east of England where it succeeds wonderfully well on light soil and under conditions of low rainfall. A still smaller variety of the same shape is the pigeon bean, which, as its name denotes, is sufficiently small to be utilized whole for feeding to pigeons.

Beans are regarded generally as a heavy land crop, but the adequate and sustained supply of moisture during the growth of the plant, rather than the character of the soil, is the determining condition, and good crops are frequently obtained on what are characteristically light soils.

The most destructive insect pest of the bean, and indeed the factor limiting its more extensive cultivation, is the Black Fly (*Aphis rumicis*), which usually makes its earliest appearance towards the end of May and the beginning of June.

The object of the bean grower should be the maintenance of uninterrupted growth in the spring whereby the plant reaches a state of development by May which precludes serious damage by the aphis. In the event of a severe attack of the fly a stunted early growth may result in the complete destruction of a crop, whilst under an attack of equal initial severity something may be saved when the plant is sufficiently advanced in growth to sustain such pods as do manage to set seed. These conditions of growth are probably secured with the greatest degree of certainty from season to season, on heavy land, but due attention to such treatment of the land as will increase its moisture-holding capacity, as, for instance, green manuring, brings lighter land well within the category of bean soils.

To grow beans well, a soil whether heavy or light, must contain a plentiful supply of lime. Being a leguminous plant and thus able to obtain supplies of nitrogen from the air, the bean does not respond well to applications of nitrogen whether contained in farmyard manure or in artificial fertilizers. Excessive supplies of nitrogen result usually in an over-growth of stem and a poor production of flowers. The use or otherwise of farmyard manure depends largely on the rainfall and on the character of the soil, for its moisture-retaining capacity is a very valuable property quite apart from its manurial value. On the other hand, the bean responds well to phosphatic manures, and in some cases the further addition of potassic manure is beneficial.

Cultivation.—Beans require a deep but not necessarily a very fine seed-bed, and unless the clods of soil are so large as to prevent the plants making their way to the surface, a rough surface after seeding provides shelter for the crop during the winter.

The crop is frequently drilled in with an ordinary seed drill, but on lighter lands it is just as often ploughed in, the seed box in this case being attached to the plough. Whether drilled or ploughed a distance of 12 or more inches is allowed between the rows. This permits of horse-hoeing and weeding, both very necessary spring operations. But apart from this a good distance between the drills and between the plants in the drill is essential to prevent too great a vegetative development, in which case the plants fruit sparsely.

The effects of too close spacing are strikingly similar to those produced by over-manuring with nitrogenous manures or growing the crop on soil in which the amount of available nitrogen is too high.

Two to 2½ bushels is the usual rate of seeding, but unless there are conditions demanding a high seed rate, the chances of securing a high yield of grain are closely related to low seeding.

When the land is known to be too highly supplied with nitrogen its effect may be modified by the use of phosphatic manures. On soil well supplied with lime, superphosphate at the rate of 3—4 cwt. per acre may be used, and on soils liable to be acid, basic slag at the rate of 4—6 cwt.

Perhaps the most serious disease to which beans are subject is "chocolate spot," generally conceded to be a bacterial trouble. The damage resulting from chocolate spot assumes serious proportions in some years, plants not infrequently being defoliated before the bean pods are fully developed. Although potash manures may not increase the yield to any great extent, there are indications that they check chocolate spot and their use is advisable therefore on soils at all deficient in potash.

Apart from the produce of the crop, beans have long been regarded as an excellent crop to precede wheat, and the progress of time has brought about no modification of what is undoubtedly a valuable procedure in wheat-growing districts.

Peas.—This leguminous crop still occupies a position of importance in the south and south-eastern counties of England. Although the stem is squarish and generally hollow, as in the bean, it differs from that plant in its greater length, trailing habit, and in the possession of large, fleshy stipules, in some cases much larger than the leaflets themselves. The leaves are compound with one, two or more pairs of leaflets placed opposite to each other on the leaf-stalk, which is finally extended to form a series of tendrils, these being in reality leaves modified into thread-like structures capable of attaching themselves to any object they may touch, and acting as supports for the weak succulent stem.

The flowers arise on stalks varying in length with the variety; the stalks bear one, two or more flowers, the number again being a varietal characteristic. The flowers are papilionaceous and the

fruits, again two-valved pods, contain a varying number of seeds. As in the case of many other plants of the order, the fruits when fully ripe open by a violent fracture of the two halves of the carpel, which twist on themselves and in so doing eject the seeds to a considerable distance from the parent plant.

The peas used in agriculture are distinguished from the very large number of culinary varieties by their usually higher degree of winter-hardiness, and by their flowers, which are blue to reddish purple. In addition, whilst garden peas are usually green, with a colourless skin, field peas are very frequently yellow and the skin coloured.

Despite the risk attending the practice, growers in near proximity to good markets, sow culinary varieties such as Harrison's Glory and Prussian Blue in sheltered positions in the autumn. Unless the winter is particularly severe such crops are ready to pick early in the summer when prices are sufficiently remunerative to balance good seasons against bad and still leave a profit.

The value of the pea as an agricultural crop is determined by the yield of grain, the haulm, although possessing some feeding value, being of quite minor importance. The pea, like the bean, has a high protein content and on this basis is one of the most valuable of the farm crops for stock feeding.

The varieties used for purely agricultural purposes are :—

Early Minter or Norfolk Dun.
Maple or Partridge
Black-eyed Susan.
Eights and Nines.

EARLY MINTER, as its name suggests, is an early-ripening sort, this feature being of considerable value in rendering the crop less liable to damage by aphis attack. The straw is of medium length and the grain a pure dun colour.

MAPLE OR PARTRIDGE is a late ripening variety with long straw. The grain is somewhat small, light-brown, and irregularly blotched with lighter coloured markings. In wet seasons this pea is inclined to produce too much haulm and the grain is poorly filled. On land that is not too clean, the haulm-producing character of this variety is valuable for holding weeds in check.

BLACK-EYED SUSAN in point of ripening occupies a position between early minter and maple. The straw is long and the grain large and dun-coloured with black " eyes," or points of attachment to the pod.

EIGHTS AND NINES is characterized by long straw and long pods. The grain is greenish in colour. The name probably arises from the fact that the seeds are closely packed in the pod and so present the appearance of considerable numbers.

Peas are very susceptible to the effect of excessive rainfall on the one hand and of drought on the other. Under conditions of the former the haulm grows to an excessive length, the flowers fertilize poorly, and if sufficiently fertilized, the seeds fail to fill

and ripen properly, whilst under conditions of moisture deficiency the haulm is very short, the pods few in number and the seed small and indifferently filled. These weather effects influence the choice of soils on which the crop should be grown. Light, sandy soils, except in districts of normally heavy rainfall, are wholly unsuitable; heavy soils, except in districts of light rainfall, are unsuitable and even on these it is frequently difficult to obtain the requisite fine tilth. When results are judged over a series of seasons good loams are the most reliable soils for this crop.

Peas, like most other leguminous crops, require an abundant supply of lime in the soil and even under the most favourable conditions cannot be grown successfully on the same soil at too frequent intervals.

As peas obtain the greater portion of the nitrogen they require from the air, they do not require artificial nitrogenous manures in any form. Indeed, the use of nitrogenous fertilizers tends to the production of an excessive quantity of haulm to which poor seed-setting and ripening are the usual accompaniments. Phosphatic and, to a lesser extent, potassic manures are beneficial. In the case of land that has been heavily supplied with farm-yard manure a small dressing of a soluble phosphatic manure will often minimize what would be otherwise an undesirable effect of excessive nitrogen.

The inability of the pea to succeed under conditions of high soil fertility on the one hand or of low fertility on the other largely determines the position of the crop in the farm rotation. Peas usually follow a cereal crop, provided the stubbles are sufficiently clean. The cultural operations in this case are simple and consist of early ploughing of the stubbles in the autumn and a second ploughing as early in the new year as possible. On light land, provided it is dry, the seed may be drilled in January; but on heavy land drilling is deferred until February or March. Drilling is usually done in rows 9—12 in. apart at the rate of 2½—4 bushels per acre. The crop should be horse-hoed when 2½—3 in. high, and then hand-hoed repeatedly until the development of the haulm restricts easy movement among the plants. The limited time available for this operation makes a clean soil a very necessary condition of pea cultivation.

Undoubtedly the best method of harvesting peas is with a pea hook, but it is at the same time the most expensive. Occasionally they are scythed, but most generally an ordinary grass mower is used. The crop requires a considerable amount of drying before stacking and in wet weather difficulty is encountered in preventing damage to the pods which lie on the ground. To obviate this the crop should be secured in small heaps as rapidly as its condition permits. Finally, peas should be stacked in long, narrow stacks in a position which exposes them to the maximum amount of wind and, if possible, on wooden frames to permit free circulation of air through the body of the stack.

CHAPTER VIII.

THE CULTIVATION AND HARVESTING OF CEREALS.

THE importance of the cereal crops of Britain is very small in comparison with those grown in other parts of the world. These crops lend themselves to large-scale management in all stages of their production. They can be cultivated and harvested much more cheaply in fields of 100 or 1,000 acres than in those of 5 or 10 which predominate in Britain. The crop of grain is dry and dense so that it can be handled and transported to this country at small cost from all parts of the world. The climate of Great Britain, except in the eastern counties, is not very favourable to the growth of wheat, and often unfavourable to its harvesting in comparison with those of the cereal districts of the world, where the grain can commonly be threshed from the standing crop in condition dry enough for indefinite storage. For these reasons the area devoted to the crop in Britain is continuously diminishing.

In Great Britain cereals are chiefly grown on the eastern side, and especially in the eastern counties, where the annual rainfall varies between 20 and 30 in. and where the atmosphere is relatively dry in comparison with that of the west. Both wheat and barley are peculiarly favoured by a dry climate but oats are more tolerant of moist conditions and for this reason are grown to advantage in the west and north.

Preparation of the Seed-bed.—Seed-beds for cereals should be clean and free from weeds before planting because their habit of growth does not effectively suppress weeds, nor do they lend themselves to efficient intertillage. The seed-bed should preferably be shallow and firm, being ploughed from 4 to 5 in. deep, because the cereal roots need to grow in a firm soil. If the ploughing is deep the surface soil does not settle firmly on the subsoil and consequently the roots are not able to obtain a firm foothold. Under these circumstances, if wet and windy weather prevails during July when the ears are forming, the roots are unable to support the straw and the crop becomes "laid." If, therefore, the seed-bed has been deeply ploughed, or is loose for other reasons, special precautions must be taken to consolidate it.

Seed-beds for autumn and winter planting, whether for wheat, barley or oats, differ from those required for spring-planting in respect of fineness of texture. In spring the main requirement is a finely-divided seed-bed from the subsoil upwards, so that moisture may be retained and prevented from rapidly drying out in the dry periods of early summer, and so that the roots may easily grow down into the subsoil, and also that moisture may pass from the subsoil into the surface soil. For autumn and winter planting the drying-out of the seed-bed need not be feared in the moist months which will follow planting, and the winter rain will certainly help to consolidate the seed-bed. On the other hand, finely-divided seed-beds, especially when the soil is composed of clay or silt, run

together and paste down under the influence of winter frost and beating rain, with the result that the surface becomes "panned," prevents the free passage of air and water, and hinders the growth of the crop. Seed-beds for cereals in autumn should, therefore, *be left rough on the surface, especially in the case of* heavy soils.

WHEAT.—In this country the wheat crop is generally taken after "seeds," peas or beans or potatoes. It is occasionally taken after roots carted or fed off early, especially sugar beet, and also after a bare or bastard fallow, and more rarely after a previous corn crop.

The soils most suited to wheat are the medium and heavy soils, provided they are well-drained. Wheat prefers a dry climate and revels in a hot, dry ripening period. If grown on light soils it is liable to suffer from drought during intensely hot weather. Varieties of wheat commonly grown in Great Britain require a long period to complete their growth, consequently they are generally planted between October and December. Spring-planted wheat is rarely satisfactory in Britain, though the greater part of the crops of Canada, as well as other wheat-growing areas, are spring-planted with varieties specially bred for rapid maturity.

Preparation after "Seeds."—After a crop of clover and grass has been taken the surface soil is left firm and tight and is generally covered with a green growth of clover, grass and weeds. Dung is frequently spread on the "seeds" before ploughing. No cleaning of the land is done unless a "bastard" fallow is taken after the first hay crop. The land should be carefully ploughed 4 or 5 in. deep so as to bury all of the dung as well as the green remains of the crop. Sometimes a skim coulter, with or without a drag chain, may be required to tuck in the green growth properly, for if any is allowed to project through the furrow crease it grows and becomes a weed. On light land the furrows need to be tightly pressed after ploughing with a furrow press or, alternatively, with the ring roller to consolidate the furrows which, when broken out of the solid layer, do not readily break or pack tightly. Heavy land does not need to be rolled. It is preferable that the land be left to weather and consolidate a few weeks, and then the seed-bed is prepared by two or three turns of the harrow. The wheat seed-bed, after "seeds," should not be cultivated deeply because this would bring the weeds and green crop plants to the surface again. The harrowing breaks only the upper part of the furrow sufficiently deeply to permit the drill to deposit the seed at the required depth; the lower part of the seed-bed is not worked by the harrow, but is gradually weathered and compacted on the subsoil by the rain and other weathering agencies during winter.

After peas or beans or another corn crop, the land should generally receive some cleaning of the surface in autumn by tractor cultivator, or other means, to eradicate couch and other weeds. It is then ploughed and left to consolidate. Before drilling the

surface is harrowed to prepare a seed-bed, care being taken not to make the seed-bed too fine lest the beating rains of winter cause the surface to pan.

After potatoes the land is generally left clean from perennial weeds but may, if the potato tops have died early, contain numerous plants of chickweed and other annuals. The surface soil is often very fine and light in texture. In some cases no further preparation beyond a turn with the cultivator is given before drilling This may be satisfactory, but this method is liable to result in the growth of annual weeds in the crop, and the finely-divided soil is very liable to "run" in wet weather and form a "pan" on the surface. A better plan is to plough the land to a shallow depth for the purpose of burying the annual weeds and the finely-divided surface soil. When the plough furrow is eventually harrowed to form a seed-bed it retains a coarser texture than when such ploughing is omitted.

When wheat is grown after a bare fallow it is very liable to damage by the wheat bulb fly, and for this reason such land should preferably be cropped with a spring-planted cereal. After a bastard fallow wheat may generally be grown without much damage from this pest. In this case the land is broken deeply with plough or steam cultivator in July after the first hay crop, a crop of silage or other early crop has been taken. It is stirred a few times with cultivators in hot weather so that the strands of couch and other perennial weeds may be baked in the clod. The seed-bed is prepared by harrowing or cultivating the land after the clods have been moistened by autumn rain. Bastard, and especially bare fallows, both of which are common to heavy land, are liable to become very fine in texture and very sticky after much rain. For this reason they should be drilled early in autumn unless planted with spring corn, in which case they should be ploughed in autumn and left over winter in the plough furrow.

The usual method of planting wheat in autumn is by the use of the drill. When this is used it is generally desirable to bury the wheat $1\frac{1}{2}$ to 2 in. deep so that, when harrowed, the grain may be too deep for small birds, such as larks and starlings, to reach. At this depth rooks will still be able to reach it. After drilling it must be properly covered by harrowing immediately behind the drill. If rooks are troublesome in the district, and especially if the planting is late, it is desirable to harrow the field again after drilling is completed. The second harrowing should be across the drilling so as to harrow out the furrows made by the coulters of the drill. Otherwise these furrows are easily followed by rooks. The second harrowing should be carried out as soon as possible after drilling before the land has become wet with rain or been frozen; if either of these conditions intervene, the second harrowing may break the surface soil too finely, with the result that the surface becomes panned by the winter's rain. If birds were not likely to injure the germinating crop, it would be preferable to sow the seed near the

surface—" surface sowing," as it is called—because seeds so sown develop into sturdier plants and produce heavier yields. But germination is very slow after the end of October, and the risk is too great. It may, however, be good policy to plant shallow when drilling is exceptionally early.

Under certain conditions it may be more profitable to broadcast wheat instead of drilling it; thus wheat is frequently broadcast upon land which, after ploughing, has been pressed with the furrow press. In this case the greater part of the seed comes to rest on the firm soil in the track made by the press, and the field is then harrowed once or twice to cover it, or again, the seed may be broadcast on the surface of potato or root land immediately before ploughing. The land is then ploughed shallowly, and the wheat deposited under the plough furrow. This method obviates bird damage to late-planted wheat and prevents panning of the surface soil which is so likely to arise when wheat follows potatoes. If wheat is ploughed under in this way some of the seedlings are liable to be killed because they fail to penetrate the furrow and reach the surface. Ploughing must, therefore, be shallow, and to help them the field may be harrowed or disc-harrowed after ploughing to break the furrows.

Treatment of Seed.—Untreated wheat seed is very liable to be attacked by bunt, which destroys the grain and fills it with bunt spores (p. 389). Formerly wheat seed used to be treated with a solution of bluestone—copper sulphate, made by dissolving 2½ lb. of bluestone in 10 gallons of water—before drilling, for the purpose of killing the bunt spores adhering to the outside of the grain. This is quite efficient for the purpose but is somewhat liable to injure germination. (Other methods of treatment are described in detail on page 391.)

The Manuring of Wheat.—Wheat is a crop which has a long period of growth. It is planted in autumn and grows through winter, spring and early summer, and is harvested at the end of summer. It produces a strong-developed root-system which penetrates and searches the soil deeply for plant food. It produces a long stem, or straw, which when overfed is liable to be laid by summer rain, with the result that the crop is costly to harvest and the grain is thin. For these reasons the wheat crop does not require very heavy manuring. Attention should be given to the character of the soil and previous manuring. If the soil is deficient in phosphates, and the previous crops have received none, a small quantity may be needed, but it is not generally necessary. In this respect it may be mentioned that the Australian wheat soils are proverbially deficient in phosphate, and each wheat crop should receive 1 cwt. or more per acre. Potash is not generally required for wheat, except upon thin, sandy soils and gravels which are very deficient. The real problem with the manuring of wheat is how much nitrogen to give the crop. For this decision experience of the fertility of the soil and a knowledge of the previous manurial

history of the field are essential. The point at which to aim is to grow "as much wheat as will stand up" in the average year, and lean a little in wet seasons. When wheat is grown after "seeds" with a coat of farmyard manure ploughed in, no extra nitrogen is required, nor is any required after a well-manured potato crop on good loam, but when potatoes are grown upon light soils, even though well manured, the crop may give a profitable return for $\frac{3}{4}$ to 1 cwt. per acre of sulphate of ammonia, because the potato crop is a gross feeder and, especially if its growth is continued in autumn, leaves little available nitrogen in the land. If wheat follows another corn crop, the land will be poor and the wheat will give a profitable return for the application of 1 to 2 cwt. of sulphate of ammonia. In general it may be assumed that the application of 1 cwt. of sulphate of ammonia will give an increased yield of 4 to 5 bushels of wheat and 5 to 6 cwt. of straw, provided, firstly, that a "plant" of wheat has been established, and, secondly, that the application does not cause the crop to be laid.

If wheat has been planted early on a fertile land in a mild winter it may have made too much growth in spring and become "winter proud." This condition results in long, thin straw and a low yield. This condition may be rectified by grazing the wheat off bare by sheep in the month of April or until the end of the first week in May.

Intertillage.—When winter is over and the wheat examined in the early spring, it will be found that frost has lifted the surface soil on some fields and the wheat is loose at the root, on others that the soil is panned down tightly by winter rain, and on yet others that the surface is still rough and cloddy, whilst in all cases it is likely to be found that a number of small annual weed seedlings are developing. To rectify these conditions spring tillage is executed, care being taken, especially upon the medium and heavy types of land, that the tillages are not carried out before the land is sufficiently dry. The field will generally be rolled with a ring roller first. On light land this may be done towards the end of March, but on heavy not before April. This will consolidate the the land loosened by the frost and check the easy passage of wire-worm from plant to plant. It will crack the surface pan if care is taken to roll at the right time when the land is neither too moist nor too dry, and it will crush the clods. After rolling the land will usually be harrowed to open the surface of the land to the air and to destroy some of the seedling weeds. In some cases, especially upon stony land, the field may then be rolled with the flat roller; this presses the stones into the soil and leaves a more level surface for the subsequent cutting of the crop. Finally, it is desirable to spud thistles and uproot docks by hand during May.

Harvesting.—A large part of the world's wheat is now cut and threshed by combined harvesters in the field where it has grown or from the swath after being cut a few days. A few people are experimenting with similar machines in this country but the

uncertain climate in most districts does not favour the method. The greater part of the cereal crops in this country is cut with the reaper and binder, built into stacks, and threshed at a later date—operations which entail much greater expense than that of the combined harvester, yet necessitated by the climate and justified by the better treatment of the straw, which is a more valuable product in Great Britain than in the extensive wheat fields of the world. For the successful operation of the combined thresher, the grain, when cut, must be hard and dry, but when using the British method it is preferable to cut wheat before it is dead ripe and whilst the grain is still cheesy in texture and there is still a trace of green in the straw just below the ear. The reasons for this early cutting are, firstly, that the grain may not shatter during the operations of cutting and stacking, secondly, because the grain continues to feed on the straw after cutting, and thirdly, because it enables the cereal farmer to get his wheat cut and shocked so that he is ready to cut his barley, a more delicate crop exactly when it is fit.

Immediately after cutting wheat should be set up in shocks of 8 to 12 sheaves. The shocks, or stooks, should be carefully formed, with the butt ends firmly placed on the ground and the ears forming an acute angle, so that rain may be quickly shed. In rainy districts it is advisable to place the shocks pointing north and south so that the sun may shine equally on both sides.

Wheat in this country generally requires to stand in the field from a week to a fortnight, according to the ripeness when cut and the weather conditions, to dry and harden before it is fit to cart, but when it has once properly matured wheat may be stacked even though damp with dew or slightly wet with misty rain, conditions in which it would be unwise to cart barley or oats. Corn stacks should be constructed on a dry stack bottom and preferably upon one which allows air freely to circulate below the rick. In building the stack it is important to keep the centre higher than the walls so that all the straws slope downwards and outwards ; in this condition rain, if it beats against the sides of the stack, does not tend to run into and damage the stack. The roof should be particularly well built. The raising of the centre must be emphasized, and the outside sheaves should be placed with care so that the butts of the sheaves overlap like slates on a roof. Corn stacks, if properly made, do not settle greatly, and are fit to thatch a day or two after building. The thatching should be done, therefore, as soon atter stacking as possible

Corn threshing in the drier parts of this country is sometimes done directly from the field, but more often after the grain has stood for varying periods of time in the stack. After stacking, the corn generally sweats slightly. If carried in bad order it sweats badly and may not be fit to thresh until the March winds have blown through and dried the stack. The threshing machines commonly used in Great Britain are large cumbersome machines provided with beater bars on the drum to rub out the grain (p. 72). The

separation of the grain from straw, chaff, weed seeds, etc., is very perfectly performed, but the operation is tediously slow and very wasteful of manual labour. It is none the less justified for the production of a good sample of barley when this is of high quality and "tender." In Canada and other parts of the world, where labour is costly, and where malting barley is not largely grown and straw is of less value, threshing machines of the peg-drum type are used. These machines knock out the grain instead of rubbing it out, blow the straw, chaff and caving away together by means of a wind-stacker in place of an elevator and do not clean the grain so well, but they are capable of accomplishing double the output with half the labour.

The average yield of wheat grain grown in this country, as returned by the Ministry of Agriculture, is 17 cwt. per acre, a crop which would be associated with about 25 cwt. of straw. Good crops may produce 20 to 25 cwt. of grain per acre and exceptional crops up to 30 and 35 cwt.

The Barley Crop.—Barley may be grown and used for one of two entirely different purposes. The best samples, those in which the grain is uniform in size and in colour, which are perfectly mature, in which the skin and cell-walls are thin and the grains of which are full of starch, as indicated by a white, mealy appearance when cut in halves, are used for malting. Inferior samples unsuitable for malting are used for stock feeding. The former often command relatively high prices, the value of the latter is governed by the price of maize and other starchy foods. In order to obtain the best quality great care is necessary in the management of the crop at all stages so as to obtain perfectly uniform and unblemished samples.

Barley is mainly grown in the east and south of England, where the drier and milder climate is advantageous to the crop. At no period of its growth is much rain required, and especially is it desirable that the harvesting period be dry so that the crop may be secured in good condition. None the less, slight showers or heavy dews during the last week or two of ripening are desirable, because these help the colour and mellow the sample. Very hot, dry weather at harvest causes the sample to be harsh and sometimes flinty in character.

The barley plant produces a rather weakly-growing root, which consequently does not easily penetrate unfavourable soil. It grows to best advantage on light and medium soils, especially when these have been prepared to form a mellow and crumbly seed-bed. It does not grow well upon heavy soils unless these are in an ideal state of texture and the season is dry. In very dry seasons heavy-land barleys may compare more favourably with those grown upon the light soils. Barley cannot be grown successfully upon sour soils, and, in fact, a comparatively slight acidity of the soil causes the plant to die in the early stages of growth. On the other hand, the calcareous soils are favourable to its growth. The straw of barley is weak and consequently the crop is more likely to "lodge"

than wheat or oats. Excessive richness of soil must be avoided, and nitrogenous manuring must be strictly limited lest the straw is unable to carry the weight of the ears.

Barley is typically taken in the rotation after a root crop. Good quality crops may be grown, especially when the roots have been carted off or folded with store sheep. If a good crop of roots is folded by fattening sheep receiving a heavy ration of cake and corn, the land becomes too rich in nitrogen, the crop is liable to be laid and the grain to be coarse. In such cases two successive corn crops are commonly taken after roots, in which case the second barley crop is more likely to be of good quality. In other cases barley may be successfully taken after wheat or other cereal, provided careful attention is given to the manuring of the crop. When soil conditions are favourable barley may be grown after potatoes and less commonly, and only when the soil is ideal, after "seeds."

Barley is normally a spring-planted crop, although in mild winters good crops of high quality barley may be obtained from autumn sowings. The seed-beds prepared for the autumn-planting of barley are similar to those for wheat, but for spring-planted crops much greater care is necessary in their preparation, firstly because dry conditions of weather may be expected to follow the spring planting, during which a badly prepared seed-bed might dry out in parts and so cause an irregular plant, and because the interval of time between planting and harvest is so much shorter than in the case of autumn-planted crops. In the latter, time and weather help to ameliorate irregularities in the germination of the seed, but in the former irregular germination results in irregular ripening.

For spring-planted barley the seed-bed should possess the following characteristics:—It should be clean and free from weeds so that the crop, which is not a smothering crop, may not suffer from weed competition, and so that the sample of barley, when threshed, may be free from weed seeds. It should be well-worked and uniform so that germination and growth of all the plants may be simultaneous, so that aeration may be complete and nitrification encouraged. It should be finely divided so that the seed may be well covered to an even depth and so that the seed-bed may hold and retain rain water for the service of the growing crop. It should be firm from below upwards, with the surface soil firmly and intimately connected with the subsoil, so that the depth of drilling of the seed may be uniform, so that root-growth may pass downwards easily from the surface to the subsoil, and so that moisture may easily pass upwards during dry weather from the subsoil to supply the needs of the crop. Lastly, the seed-bed should not be too deep. For barley, according to circumstances, the depth should be between 3 and 5 in. If too deep the hollow spaces left by the ploughing are much more difficult to eliminate by subsequent cultivation, and the seed-bed is likely to be hollow, with imperfect contact between surface and subsoil ; such hollow

seed-beds not only prejudice the growth of the barley roots, but in dry seasons are likely to dry out so that the plant suffers from lack of moisture, and in rainy seasons the earth subsides into the hollow and the crop becomes root-fallen and laid. These characteristics, essential for the growing of a malting sample of barley, are desirable for all other spring-planted corn crops. Consequently, the methods about to be described for the preparation of seed-beds suitable for barley may be adopted for those of other crops.

In the preparation of a seed-bed for barley on light land after early roots, consideration must be given to the surface soil after the roots are removed. If the roots have been carted in dry weather, the texture of the surface will be friable, but if carted in wet weather, and especially if folded in bad weather, the surface, down to a depth of 2 to 3 in., may be left in a pasty condition. This should not give much trouble if the field is cleared in early winter so that frost has time to rectify the texture before or after ploughing, but if otherwise, very careful management will be required. The preparation of a seed-bed for the previous root-crop should always include deep ploughing and cultivating, thus the lower depths of the surface soil, below 3 to 4 in., should be left in mellow condition after the removal of the crop and ideal for the ramification of the barley-roots when they reach this depth. It is, therefore, unnecessary, and indeed harmful, to plough such land deeply for barley. As soon as possible after the roots are cleared, and other work on the farm permits, the land should first be ploughed to a shallow depth of 3 to 5 in., according to circumstances. It should be left in the plough furrow untouched, so that frost may weather the land. In some cases, and especially if trampled, pasty soil has been ploughed under, it should be ploughed a second time in the new year when the soil is sufficiently dry for the purpose. The second ploughing re-exposes the land to the weather, so that this becomes very friable and at the same time checks the growth both of perennial and annual weeds. Subsequently, whenever the land is dry enough, the seed-bed can be very easily prepared by two or three turns of the harrow, and, if necessary, a rolling to tighten and level the seed-bed just before drilling. If a second ploughing has not been given then the seed-bed will require deeper and more thorough preparation before drilling. This may be accomplished by one or two turns of the cultivator or disc harrow to break up the original furrow and disturb the weeds. It is quicker and cheaper than ploughing but not so efficient in producing uniformity of the seed-bed at different depths. After these cultivations the seed-bed may be prepared as before by the use of harrow and roller. If the land cultivates up roughly and leaves a number of harsh clods, the roller will be required to crush and reduce these to finer texture before the final harrowings.

In the case of barley after late-folded roots, the late-folding is likely to have damaged the texture of the surface soil, which must be rectified before the seed is drilled, and the seed-bed must be

prepared at a time of year when dry weather is likely to prevail, so that the seed-bed is liable to dry out completely during its preparation unless great care is taken. Under these conditions time does not permit of two ploughings. A deep ploughing would turn down to the subsoil in an unweathered condition the damaged surface soil, in which position tillages, whether by harrow, roll or cultivator, would be powerless to rectify it. Commonly such land, when in a sufficiently dry condition, is ploughed very shallowly. Each day's ploughing is then rolled and harrowed the same day, so that the plough furrows may be left covered with a little fine soil and prevented from drying out until the ploughing is finished. The seed-bed is completed by a succession of rollings and harrowings until the texture is sufficiently reduced. This practice in dry weather frequently results in the formation of a harsh, " knobbly " seed-bed. An alternative method consists of using the disc harrow on the trampled surface before ploughing, in order to ameliorate the damaged texture. This operation should be carried out when the soil begins to dry. By such cultivation, repeated if necessary, the most badly trampled surface is broken up and the field covered with friable soil to a depth of 1 to 1½ in. Then the land is ploughed to a shallow depth so that the friable soil on the surface falls upon the subsoil as the furrow is turned with the rest of the furrow lying above it. The area ploughed each day should be rolled and harrowed the same day to prevent drying out. When ploughing is completed the seed-bed may be prepared by again using the disc harrow to break down the plough furrows, and finally prepared by harrow, and roller, if necessary. This method, by which a shallow layer of crumb is produced on the surface of the unploughed field by the disc harrow before ploughing as well as by the disc harrowing as soon after ploughing as possible, is particularly appropriate for the quick preparation of seed-beds, because the surface part of the land is broken down before ploughing and falls upon the subsoil in a condition which needs no further treatment before the seed is planted, and the remaining part of the furrow (unbroken), being shallower, is the more easily and quickly broken down afterwards. This general method for the preparation of seed-beds is, therefore, particularly appropriate for dry weather conditions and is, in fact, largely practised in dry climates.

When a seed-bed for spring corn is being prepared upon heavy land which has previously carried a corn crop, the chief factor in the breaking down of the texture to a crumbly condition should be the weathering of the soil chiefly by frost and thaw. Implements should be used to facilitate this weathering, but the roller should not be used if the seed-bed can be prepared without it, because the use of the roller is so liable to damage the undertexture of heavy soils whilst these are still moist. Cultivators, harrows and disc harrows are appropriate implements for use in preparing seed-beds on such soils after ploughing, but the main point to emphasize is early ploughing, so that the plough-furrow may receive the full

benefit of winter frosts. With these ideas in view, the following procedure may be adopted. The stubble, if weedy, should be cleaned directly after harvest by the use of a broadshare or cultivator. The field should be ploughed in late autumn or early winter to a depth of 4 to 5 in. It should be left untouched till dry weather in spring causes the land to dry and the top of the furrows to change colour. Then, and not till then, it should be cultivated to the full depth of the ploughing across the furrow. This breaks the furrows, causing them to crumble, brings clods to the surface and allows the finer parts of the soil to settle upon the subsoil. If the clods are "tender" and it is desired to crop the land immediately, the cultivating should be repeated once or twice and the land harrowed a time or two until it is fine enough for drilling. When this stage is reached it should be immediately drilled, since heavy land ready for drilling is in a critical condition, for if heavy rain falls, the moisture is held by the soil, which becomes sticky, and any subsequent cultivation by drilling, harrowing, etc., spoils the mouldy "crumb"-structure which has been obtained by weathering and by patient endeavour. If after the first spring cultivation the land breaks up "raw," in a condition which will not readily be reduced to a seed-bed, it is preferable to leave the field for a week or fortnight for further drying and weathering before proceeding by similar methods to complete the seed-bed. In the somewhat rough condition left by the first cultivation, the texture of the field will not necessarily be injured by rain, since this can drain through the rough soil whilst it is absorbed by finely divided heavy soil.

Seed and Drilling.—Seed-barley should be perfectly true to variety, since mixtures of varieties will inevitably produce an uneven sample. It should be free from weed seeds, and, so far as can be ascertained, free from disease. Blindness (Helminthosporium) and smut may cause serious loss of crop. The sample should possess a high percentage of germination and at the same time it should germinate regularly and strongly, so that the crop makes a uniform start. The sample need not possess high malting quality, in fact, a coarse sample, provided the variety is right, with a high nitrogen content, is preferable for seed purposes to a mellow, starchy sample, characteristic of malting samples, because the former will generally give more vigorous growth.

Treatment of Seed-Barley.—Barley is not generally dressed before planting, but none the less, the crop frequently suffers loss of crop from covered smut and the blindness caused by Helminthosporium, both of which can be largely prevented by the formalin treatment, described for bunted wheat (p. 391).

In drilling, the greatest care should be given to depositing the seed at a uniform depth at about 1 to 1½ in. below the surface on a firm bottom. After the seed has been drilled it should be harrowed in immediately behind the drill, and it is generally advisable to cross-harrow, especially if rooks are troublesome. Finally, the field is generally rolled to press the seed firmly into the soil and

to prevent drying out of the seed-bed. But this practice is often withheld on heavy land if the seed-bed is rather moist or if drilling has taken place in the early part of the season, because the finely divided and level surface is liable to "run" together and when dry to form a surface pan or crust through which the seedlings may be unable to force their way.

Intertillage.—The intertillage of spring-planted cereal crops is carried out for similar purposes and with similar implements as that described for autumn-planted cereals. Wireworms, which are liable to be particularly troublesome to spring corn, may be prevented from "running" so freely from plant to plant by heavy rolling. If a crust or pan is formed before the seedlings have reached the surface it may be broken by the use of a ring roller. Barley is specially benefited by light harrowing, which does little injury to its foliage and kills many seedling weeds, so preventing their subsequent competition with the crop.

The Manuring of Barley.—The manuring of barley requires to be carried out with care and judgment, so that a large crop of the highest quality may be produced. Excessive quantities of nitrogenous manures result in the production of laid crops of uneven grain or of coarse-grained samples. The aim must, therefore, be to take into account all the factors in each case and try to attain the happy mean with a vigorous growth of foliage ripening to produce a bountiful crop of good quality. The field upon which barley is to be grown should be mellow rather than rich in humus, so that a good texture can be easily obtained. It is not, therefore, general to apply farmyard manure for barley. Excessive nitrogenous manure leads to the production of long, sappy straw which is liable to be badly laid. In this case ripening is both delayed and irregular, and the grain is liable to be variable in size and in colour. Excessive nitrogenous manuring also leads to the production of a coarse grain containing too great a quantity of nitrogenous substances instead of a plump, mellow grain, full of starch, which is the condition desired by the maltster. Nitrogenous manuring must, therefore, be adjusted to the known conditions of the field and to its previous cropping and manuring. After a folded crop of roots on medium land, no extra nitrogenous manure will be required, but when barley is taken after a corn crop on average land a dressing from ¾ to 1½ cwt. of sulphate of ammonia will generally be required, and should preferably be applied and harrowed in at the time of drilling. The barley crop is nearly always benefited by phosphatic manures, which favourably influence the crop at several periods of its growth. Phosphatic manures help the development of the somewhat weakly root of the barley. They tend to stiffen the straw. They certainly influence the ripening of the grain and make this earlier and help the quality of the crop. For barley soluble phosphates in the form of superphosphate are preferable to the insoluble phosphates. The applications should be at the rate of 2 to 4 cwt. per acre, according to the character of the soil and the previous

phosphatic manuring of the field. Potash manuring is not largely required by the barley crop unless the soil is notably deficient and provided the field receives occasional potash for other crops in the rotation. When barley is grown upon soils deficient in potash, as for example, many of the light sands and gravels, 2 to 4 cwt. of kainit per acre should be applied.

Harvesting Barley.—In harvesting and carting barley takes precedence of all other corn crops because its quality can be so quickly spoilt by weather. Barley must be dead ripe when cut. The straw must be completely yellow throughout, with no green ears in the field ; the heads should be bent over and sickle-shaped ; the grain should be not only firm but hard. When these conditions prevail, and not till then, the barley should be cut. In this country barley is commonly cut with the reaper and binder and, provided there is not a great quantity of clover or green material in the butts of the sheaves, it should be shocked the same day. If there is, however, and the weather is fine, the sheaves may be left on the ground for a day or two for it to dry before the barley is shocked.

Barley must be completely dry when carted and stacked. It must not be carted whilst moist with dew, and carting must be stopped if rain comes on. If " seeds " have not been sown with the barley and there are no green weeds, the crop may be fit to cart within a few days of cutting, because the crop is nearly dry when cut. But if the butts contain any green material barley must in no case be carted too quickly, for otherwise it is very liable to heat in the stack, with the consequent spoiling of the quality. When barn room is available this should be allotted in the first place to barley, and when stacked in the open the thatch should be put on as soon as possible to prevent heavy rain from wetting the sheaves in the roof.

THRESHING.—In some cases barley may be threshed directly from the field, a practice which saves a considerable amount of labour, but this is not to be recommended for the best samples because the sample of barley is mellowed by a few weeks in the stack, and because such quickly-threshed samples are liable to contain a few moist grains which spoil its uniformity. The best samples are generally threshed during October, when the greatest demand is developed for malting barley. In threshing great care must be taken not to injure the grain. The threshing machine must be accurately adjusted, and in particular the hummeller must be carefully adjusted so that the awn is not broken off too close and the grain exposed. Such exposure, whether by careless breaking of the awn or by other means, is a fatal fault with malting barley, because all exposed parts of the grain, when moistened for germination, are liable to develop moulds which may kill the germ and destroy the starch.

A ' malting " sample of barley should possess the following characters. All the grains should be ripe and possessed of high vitality so that when moistened they will germinate uniformly, so that at a

given time, when the malt is dried off, all the grains may have developed to the same stage and contain the maximum amount of diastase. The sample should be in good condition, that is to say, it should be dry and the grains plump and filled with starch. The grains should be thin-skinned and transversely wrinkled, indicating that the cell walls are thin and easily broken down during fermentation, giving a quick conversion of starch to sugar. The colour of the sample should be guinea-yellow, bright in appearance and uniform. Irregularity of colour indicates some fault, thus the grey and dark colour of some grains may be due to wet weather in the shock or before cutting, and discoloured ends may be due to "heating" in the stack. The smell must be clean and free from taint of must, indicating dampness, or sweetness, indicating heat. Finally, there should be an absence of shrivelled, damaged or sprouted grain.

The average yield of barley in this country, according to the returns of the Ministry of Agriculture and Fisheries, is about 16 cwt. of grain associated with about the same weight of straw. Good crops reach as much at 25 cwt. of grain per acre, whilst exceptional crops may reach 30 cwt. per acre.

The Oat Crop.—Whilst crops of wheat and barley are generally grown for purposes of sale, the oat crop is largely grown for home consumption and fed to stock, although considerable quantities are sold for feeding town horses, and a smaller proportion for oatmeal. Oats grow to best advantage in a somewhat moist climate, and for this reason are more commonly grown than wheat and barley in the west and north. They can be grown on many types of soil, are tolerant of slightly acid conditions and grow well on some peaty soils, but they do not flourish on thin, light soils in dry districts. The chief consideration in managing the crop is to produce quantity rather than quality, since no special value attaches to this as in the case of barley, but none the less, it is very important that the grain be well filled and the percentage of husk as low as possible.

In the west and north the crop is mainly spring-planted, but in the drier districts of the south and east winter oats are becoming increasingly popular, largely because they do not suffer seriously from "frit fly,' an insect which is liable to cause serious loss to late-planted spring oats in dry districts.

In moist districts oats are generally taken after the "seeds" layer, and they may also be taken with advantage after roots and potatoes. In dry districts oats may also be taken after roots, especially when the land is very rich, but not as a general rule after "seeds." In all districts oats are frequently taken as a second corn crop after wheat, barley or oats again.

Whilst the specially well-prepared seed-bed, so necessary for barley, is not essential for a good crop of oats, it is none the less important that a good seed-bed be prepared if good crops are to be grown. In general the seed-beds requirements of winter oats and methods of preparing them are similar to those of wheat and of

spring oats to those of spring barley. One special case, in which oats are taken as a spring-planted crop after " seeds " in northern districts, may be described. The seeds in this case will generally have been down for three or more years and will have been grazed as bare as possible during autumn. In this condition the field should be ploughed 5 or 6 in. deep, preferably with a crested furrow. Since it is important to keep the turf buried, cultivators are not generally used for the preparation of the seed-bed. The seed bed is prepared by frequent harrowings, at first in the same direction as the ploughing, until the furrow has settled, then across the ploughing until the sharp teeth of the harrow have worn through the greater part of the furrow and prepared a seed-bed. In certain circumstances, disc harrowing across the furrow can be advantageously practised in place of the ordinary harrowing, since this operation, properly executed, will not tend to bring the turf to the surface. The oats may then be drilled and harrowed in as for other cereals.

Seed and Seeding.—Since oats are frequently cut at an early stage of maturity to prevent the crop from shedding, care must be exercised in selecting the seed to reject immature samples. Plump oats with a high percentage of germination and freedom from weed seeds should be selected. Whether for autumn or spring planting it is desirable to plant early, in autumn so that the plant may become well established before winter, and in spring so that the plant may have become well established and begun to tiller before the advent of frit fly, which may cause serious damage to oat crops planted after the third week in March in dry districts.

The intertillage of oats is not different from that of wheat and barley, except that oat foliage is more tender and therefore more easily damaged by intertillage. For this reason care must be taken not to harrow oats too severely.

The Manuring of Oats.—As oats are grown largely for home consumption and the chief consideration is to produce a large crop, manuring should, therefore, be on a slightly more generous basis than for barley. None the less, it is important not to manure excessively and so obtain a badly laid crop. As with all other crops, attention must be given to the previous cropping and manuring and to the manurial deficiencies of the soil upon which they are grown. In general oats have no special requirement for any element of plant food and therefore require a balanced manuring.

If oats are to be grown after a three-year layer in which the growth of white clover has been encouraged by the use of phosphates, the following oat crop should require no further manuring, but if oats are grown after wheat on heavy soil naturally well supplied with potash, the oat crop should receive 1½ cwt. of sulphate of ammonia and 2 to 3 cwt. of superphosphate, to be harrowed into the land before drilling.

Harvesting.—The oat crop is cut at an earlier stage of maturity than either barley or wheat, because oats are liable to shatter when

fully ripe, because the oats continue to ripen in the sheaf after cutting and because when oat straw is cut before becoming dead ripe its value as cattle food is much greater than that of ripe straw. *Oats are therefore cut whilst the straw is still slightly green and before the chaff flies. A useful test is to take a handful of growing oat ears by the straw and shake the ears. If the chaff begins to shatter the oats are fit to cut.*

Since oats are commonly cut at an early stage of maturity, provision must be made for the crop to dry out before carting. Few sheaves should be put into each shock so that the wind may blow through them easily, and the crop must be left in the field for a long period before carting. It is rarely possible to cart oats in less than a fortnight after cutting. If carted before the sap has completely dried out, the oats heat in the stack and the value of the corn is seriously reduced. In northerly districts special precautions are often taken to reduce this risk of heating. The stacks are generally smaller, and a triangular wooden "boss" is often placed in the centre of the stack to facilitate the ventilation and drying of the stack. In other cases a layer of faggots may be placed in the middle of the stack for the same purpose.

YIELD OF OATS.—According to the returns of the Ministry of Agriculture, the average crop of oats amounts to about 15 cwt. of grain per acre. Such a crop would be associated with about 1 ton of straw. Good crops of oats should yield 20 to 25 cwt. of grain per acre, with 30 to 35 cwt. of straw, and exceptional crops may produce 30 to 40 cwt. of corn with 2 to 2½ tons of straw.

CHAPTER IX.

THE CULTIVATION OF PULSE, ROOT AND FORAGE CROPS.

PULSE CROPS.

Beans.—These are sometimes sown in the autumn, and are then known as "winter beans," as the varieties used are hardy, and are able to withstand the cold of a moderately severe winter, though they are sometimes killed, especially if the land be wet from want of drainage. Winter beans are fit for harvesting earlier than spring beans, and are less liable to injury from the green and black "flies" (aphides), which do much harm to late beans. As the "flies" do not, as a rule, appear until July, it is a decided advantage for the beans to reach a stage in which they are past injury.

Beans do best on the stronger soils, especially those containing a fair percentage of lime; in fact, beans, as in the case of wheat, will grow on the heaviest clays in this country. The light soils in the drier districts are not so well adapted to their growth, and the crop is often disappointing in these cases.

Beans are rather an uncertain crop, and liable to be affected by severe frost. They are, therefore, more suited to the genial climate

of the southern portion of Great Britain. On heavy land beans are sometimes taken as a cleaning crop in the place of roots, and the success of the crop may then be taken as a test of clay-land farming. As noted elsewhere, beans, being a leguminous crop, form a good preparation for the succeeding wheat crop.

The seeding is simple. A piece of land which has grown wheat on heavy soils or barley on the loams is dunged and ploughed immediately after harvest, and, after it has been harrowed to a rough seed-bed, the beans are drilled and covered in by harrowing. It is a common practice in the north of England to ridge up land in the same way as for turnips, the ridges being 24 in. apart. Farmyard or other manure is put into the ridges, the beans are sown broadcast, and the ridges are split back over the manure and the seed. The ridges are harrowed down just before the beans appear above ground, and thus the growth of weeds is checked. Or, in other cases, the ridges may be split back over the manure first, and then the seed drilled on the top of the ridge in a similar way to sowing mangels or turnips on the ridge.

Another very simple method of planting followed on wet soils is "ploughing in." In this case a small seed hopper or drill is attached to the beam of every second or third plough, according to the distance apart it is required to place the rows, and the seed is simply dropped into the bottom of the furrow and covered as the work proceeds.

"Dibbling" by hand is an old and cherished method of planting beans still followed in a few places, the beans being dibbled in the unbroken furrow and afterwards harrowed in. This method has the advantage in wet seasons of allowing the planters to get on to the land weeks earlier than it would be possible to put horses on for drilling purposes.

It is very necessary to plant the beans early in the autumn, otherwise they are not so well able to withstand cold weather. As soon after harvest as possible is, therefore, the correct time for planting beans. Nevertheless, the greater portion of the bean crop is perhaps planted in the spring, bean-sowing being the first seeding operation after winter. When beans are drilled in spring the land first requires harrowing with heavy harrows to produce a seed-bed. The seed-bed need not be particularly fine. After drilling, two or three harrowings will be required to cover the seed with soil. With the exception mentioned above, beans are not sown broadcast, as it is impossible in that case to thoroughly clean the crop.

After Cultivation.—Beans, which are drilled in wide rows on heavy land which cannot be worked during winter, should be cleaned by the hand-hoe and the horse-hoe. A thorough tillage should be effected, especially among the winter beans. A single-row horse-hoe is the best implement for the purpose of loosening the ground, and this should be followed by the hand-hoe. On lighter soils, spring beans may be cleaned with a three-row horse-hoe, as the object is cleaning rather than tilling. The hoes should

be kept going until the beans have grown so high that further working among them would be injurious.

HARVESTING.—*Beans should be cut when the leaf has fallen, but it is not till some time after cutting that the corn becomes brown and hard.* The crop is occasionally mown, more often cut with a fagging-hook, and still more frequently with a reaping machine, though the hard stalks are very injurious to the knives. When the pods grow close to the ground, it is necessary to allow the crop to become riper than for cutting, and to pull the plants up bodily by hand. Beans are cut, and afford work for men, when the weather is too wet for employment to be found upon other corn crops. They should be tied and stooked, and, after remaining in the stook for a long time, they are stacked in any but very wet weather. A little outside moisture is not very detrimental, as the stout, stiff stalks allow air to draw freely through the stack. Beans should not be used as food until they have been stacked for the greater part of the year, and are better if allowed to stand over the summer; the threshing is best delayed until they are required. The sale weight is 19 stones net (= 266 lb.) per sack of four bushels. The straw, or haulm, though not so valuable as pea straw, is nutritious, and the upper portion is very palatable.

The yield of the bean crop is from 30 to 40 bushels of grain, and some 25 to 30 cwt. of haulm or straw per acre.

Peas.—This crop grows best on the lighter descriptions of sous, such as the sands, gravels, and freer-working loams, especially when these soils contain a fair percentage of lime.

Peas are occasionally drilled in the autumn, but the practice does not gain ground, most growers finding that the crop does as well when sown in the spring. Peas are, as a rule, planted on a barley stubble which is broken up in the autumn, very commonly after the conclusion of the wheat-seeding. It is generally found that peas flourish best on a stale furrow, and that beans do best on a comparatively new furrow; therefore in ploughing in the autumn, the pea land should be turned over first. Peas are sown at different periods, according to the varieties. The field-pea, of which there are several sorts, distinguished by bearing a blue blossom, should be sown as early as possible in the spring. The white peas and round blues, such as the Prussian blues, all of which bear white flowers, should be got in next—some time during February or March. The soft, wrinkled peas, grown for culinary purposes, should not be sown too early in open field culture, and except for very early picking should not be put in until April, or, being tender, they will probably be injured by frost.

Peas require a finely-prepared seed-bed, and should not be drilled when the land is at all sticky; the more tender varieties require comparatively better seed-beds than do the hardier kinds. It is rarely advisable to plough pea land a second time, but it should not be trampled on while wet below the surface, or a fine under-tilth will not be obtained. It is better to delay the seeding than to

puddle the ground by tramping it too soon. If the land is harsh and unkind it should be stirred first with a scuffler, then with the drag-harrows, then with light harrows, and, if necessary, reduced by rollers. If the land is in a mellow state the drag-harrows will be sufficiently heavy to stir it, and the lighter harrows will perfect the tilth. The seed should be drilled whilst the land is friable, and covered in by sufficient harrowings to render the peas secure from birds.

After Cultivation.—Peas should be harrowed just as the shoot begins to peep above the ground. If used at this stage the harrow destroys many small weeds, and opens the soil immediately around the individual plants with beneficial effect. The crop should be harrowed and rolled when about three inches high, whilst hand-hoeing should be commenced early, and continued until the rows meet, and the hoes can no longer be worked.

Harvesting.—Peas should not be allowed to ripen before being cut, or many of the pods burst, and the peas fall out during the turnings to which it is necessary to subject them while in the field. It is sufficient that the haulm should be yellow, and the pods tough and likewise of a yellow colour. All peas should be cut with a pea-hook, and should be worked up during the operation into small heaps or "wads." If the peas are mown by a scythe, the pods are liable to be cut open, or to be left on the ground on the base of the haulm. After the crop has lain in wads until these have become somewhat dried, the heaps must be turned over. From time to time they must again be turned, especially in wet or dull weather, when, if not turned, they become mouldy both in the middle and at the bottom of the wads. If carted before they are in fit condition, they become mouldy in the stack. It is particularly necessary that the softer or wrinkled varieties should be stacked in good condition, or a very large proportion of the peas will be spoilt. When they are being threshed, care must be taken that they are not split, or they will be useless for seed purposes. It is often necessary, especially with the softer varieties, to take off the steel bar from the beaters to avoid too hard hitting. A sack of peas (four bushels) should weigh 19 stones (= 266 lb.). Pea haulm is the most valuable of the straw fodders, and is particularly suitable when chaffed or steamed, for dairy cows and ewes.

The yield of grain is from 30 to 40 bushels per acre, together with some 25 cwt. of straw or haulm.

ROOT CROPS.

Preparation of the Land for Root Crops.—This occupies to a greater or less extent nearly every season of the year, although the time at which the work is most actively carried on is during the seasons of autumn cultivation (immediately after harvest), winter ploughing and spring ploughing, to which may be added early summer stirrings, when the actual seed-beds are prepared. (*See* (Chapter III. on Tillage.)

The process of cleaning is much more easily effected when the first stirring or ploughing is done on dry land in dry weather. The comminution of the land is very difficult when it is in a wet condition, and the endeavour in bringing land to a tilth is to work it so that none of the operations cause any portion of it to "puddle" or become annealed. When land is trodden upon or worked while it is in a wet or sticky condition it dries into harsh clods, and these clods, when reduced by force, as by rollers or harrows, do not fall down into a soft, mellow powder, but into small, angular particles which have not the power of retaining moisture during droughty periods.

A special effort should always be made to prepare a piece of land for the mangold crop, for mangold is best sown in early spring, at a time when the perfect tilth required is often difficult to obtain. The most approved method of preparing the land is to choose a piece which is nearly, if not quite clean, and to fork out any small pieces of couch, so that the work in the spring may be directed solely to the obtaining of a tilth, without any hindrance being caused by cleaning. After the couching, the land should be dunged with long dung, and turned over in dry weather, when good working in the spring will be ensured.

It is not advisable to hinder the spring seeding of the cereal crops by employing the horses on the fallows; consequently, until the greater portion of the corn is sown, it is not usual to do much to the fallows. If, however, the work is forward, the fallowing operations will be made more easy if the land is ploughed or scuffled in March, provided the weather is favourable. Steam cultivators and steam drag-harrows are particularly valuable at this season, as by their use the greatest advantage from a short spell of fine drying weather can be obtained, inasmuch as a large tract can be worked. By using these heavy implements first, the horse-work is greatly lightened, as the most severe strain on the horses occurs during the first moving of the land. As the season progresses, the cleaning and tilth-preparing operations should proceed, and, if the dung has not been got on during winter and the earlier part of spring, it should be carted on whenever an opportunity should offer. Dung for roots, when applied in the spring, should always be put on in a rotten condition, as the crop will speedily need to make use of it, so that there will be little possibility of its fertilizing ingredients being washed out before the plant can take them up.

The method of preparing a tilth on the root fallows has already been discussed in the chapter on Tillage, but a few further remarks on the subject may here be added.

The preparation of the land for the root crop must be carried out in such a manner as to result in the production of a deep mellow tilth. Where the land permits it, the furrow should be ploughed at least six inches deep, and the whole of the land which is moved should be made into a friable tilth. If the land is wet, and in a moist, sticky condition below the surface, a proper tilth cannot be

obtained unless the under side of the furrow is brought to the surface to be subjected to the disintegrating effect of the weather, the chief factors of which—rain, wind, sunshine and frost—all help to shatter the clods. If heavy land is turned up when wet, and great care is not exercised in its management, it is liable to aggregate into "nubbly" brick-like clods, unless there are a considerable number of alternating frosts and small showers to prevent this. At the same time, if circumstances permit, and the clods become quite dry, then, on being rained upon, they will lose their adhesive properties, and the particles will fall down to a fine mould. As it is uncertain, however, when the rain will fall, there is great risk in this latter process, as the season may become too far advanced before advantage can be taken of it, and the crop may not be sown soon enough to afford as large a yield as if sown earlier. The light frosts which often occur during spring are most useful, and should be utilized on all occasions. When frosts are likely to take place, it is advisable to stir the surface with harrows, so that a moist side of the clod may be brought under the influence of the cold; and when the clods are in a frosted condition, which may perhaps only last an hour or two after sunrise, a special effort should be made to move them, as they will break much more easily for being stirred while frozen.

There is a large breadth of swedes and turnips sown in the north of England, where the land is not again touched by the plough, after the good stubble furrow which has been turned over in autumn or early winter. The land is allowed to become thoroughly dry, and is then broken up by grubbers and harrows to the depth of the winter furrow. Thus the friable soil, which has been exposed to the action of frost, is kept at the surface to braird the turnips (*i.e.*, to promote the growth of the seedling plants), whilst the moisture is likewise retained in a dry season.

The cleaning and tilth-preparing operations for roots are carried out on practically the same lines as those recommended for autumn cultivation. As, however, fine seed-beds are required, the final operations must be performed more carefully and delicately, as there are fewer opportunities of correcting errors. Great care must be taken not to plough during wet weather, nor to harrow the land while it is wet or immediately before rain, or it will run together, forming a paste on the surface, which, on drying, will set like cement, and destroy the tilthy properties of the soil, whilst a large amount of fresh work, entailing a corresponding loss of time, will have to be done. It is impossible to convey on paper the circumstances under which it is advisable to have the land harrowed down on the one hand, or rolled down on the other, when leaving it. Trifling conditions with regard to moisture, the amount of work put into the land, the weather present and prospective, and various other circumstances, have to be taken into consideration, and can only be decided upon by observation in the field at the time. Many crops of corn and of roots are seriously reduced in yield owing to the final

working being done by the harrow instead of by the roller, and *vice versa*.

The general principles to be observed are that it is injudicious to leave the land rolled down when it is moist, or when rain is expected before the surface has become "hazelled," or dried into the light-brown colour peculiar to land freshly stirred. It is unsafe to harrow it while very wet, as it can hardly fail to set hard if it dries quickly. If the land is dry and puffy, so that moisture may escape before seeding is commenced, and before the moisture which would ascend from below by capillarity has had an opportunity of rising, it should be rolled in preference to harrowing. A good tilth retains moisture. If a tilth is fine it is able to draw up a large amount of water from below, but it must be sufficiently compressed for the particles of mould to touch one another on all sides, or the capillarity is weak; therefore, very light dry tilths must be rolled. But if a tilth is consolidated while wet, then, instead of the particles being brought close together, so as to assist the upward flow of moisture, these particles will be, as it were, driven in amongst one another, forming a tough paste and destroying the capillarity, so that the soil on the immediate surface will receive no moisture from below. As, moreover, the soil will be losing it by evaporation from above, the moisture will so effectually disappear, that any seed sown will be unable to germinate until rain falls. Want of judgment in the management of the final workings is responsible for the greater portion of the losses of plant in root crops, as well as the indifferent growth of the plant when up. The knowledge required can only be obtained by constantly witnessing, or taking part in, the operations themselves. It is considerations of this kind which, though apparently trifling, make all the difference between successful and unprofitable farming.

Seeding of Root Crops.—Root crops are sown on the ridge or on the flat, according to the district and climate. The ridge system is that in which the land is laid up in ridges two feet three inches or more apart, and the seed is sown along the top of each ridge. This is practised chiefly in wet districts or on heavy land, the ridge shooting off excessive moisture, which would otherwise be injurious to the growth of the crop. The flat system is carried out in dry districts, and on light dry soils. The moisture is retained longer during droughts than when the land is laid up in ridges into which the sun can penetrate. It is usual to put the dung on the land at some time previous to the final preparations for the seed-bed, when the roots are to be drilled on the flat, so that it may become incorporated with the soil; but, in the case of the ridged land, dung is applied just before the final ploughing. The land, already worked to a tilth, is ridged, and the dung is placed in the furrows; the ridge is then split back over the dung, thus forming a new ridge upon it, and on this the seed is afterwards drilled.

Mangel Wurzel or Mangold.—This is the first root crop drilled. If the land is free from annual weeds, seeding may be commenced

much earlier than if these pests are abundant. If this freedom from weeds has not been secured—and it very rarely is—it frequently happens, during cold seasons, that the weeds grow more freely than the mangold, and the crop becomes so foul that it is impossible to clean it without cutting up the plants, so that it becomes necessary to re-sow the field. Therefore, though the first week in April may be looked upon as a good season for drilling mangold in one district, equally good farmers in another district would not put the seed in before the first or second week in May. Mangold does best on strong loams, though with lavish manuring it can be made to grow on almost any soil. It is a very difficult crop to raise, because of the trouble involved in getting a full plant. For this reason a little swede seed is frequently mixed with the mangold seed; if the mangold is a full plant the swedes are taken out, otherwise they are left to occupy the gaps. The transplanting of small-topped kohl rabi is a still better means of filling up such vacancies.

A perfect tilth is necessary, and this when dried should be consolidated so that the seed can be deposited at a uniform depth. If the tilth is loose, the moisture does not rise sufficiently near the surface to promote germination of the seed, which must not be deposited at a depth greater than from half-an-inch to one inch in the soil; otherwise it does not come up at all. The final working at the time of drilling must be regulated by the dryness of the tilth, and the probabilities of rain. The seed is sown either without manure, with liquid manure, or with dry-compost manure, as, in fact, are the seeds of all the root crops.

Although mangolds and turnips resemble one another as far as the cultivation of the ground is concerned at a preparation for the crop, they differ considerably as regards their manurial requirements. The mangold may be described as a gross feeding plant, requiring a liberal all-round manuring, containing the three essential ingredients of plant-food liable to run short in the soil—viz., nitrogen, phosphoric acid and potash. It is therefore generally grown with heavy dressings of farmyard manure, to which additional supplies of artificials are frequently added. Mangolds possess a strong tap-root, which strikes deeply into the soil, so that they are able to keep themselves fairly well supplied with mineral ingredients during the growing period, but they have difficulty in obtaining sufficient supplies of nitrogen when making rapid growth. In these circumstances it is the custom to apply some quickly-acting nitrogenous manure, such as nitrate of soda, at the rate of one to two hundredweight per acre as a top dressing at short intervals. Artificial additions of phosphates and potash are also often added at the time of sowing the crop, and although the effect of these is not so marked as in the case of a nitrogenous manure, still it is a wise precaution on certain soils when bulky crops are being grown. On some land a dressing of common salt will be found to have a beneficial effect, and in these cases it will be unnecessary to use any extra supplies of potash.

Manurial experiments carried out in many counties during the last few years tend to show that moderate dressings of dung—say, 12 tons to the acre—can be profitably supplemented with a suitable mixture of artificial manures in growing mangolds.

Sugar Beet.—This crop is capable of being grown on a wide range of soils. If it is to be grown successfully, however, it is essential that the soil should not be acid. As a rule the lighter loams are to be preferred, provided they have sufficient depth, for the task of harvesting beet grown on very sticky land is always difficult and expensive. The lighter types of land are capable of growing moderate crops of beet with a high sugar content. Much sugar beet is also grown on fen soils, where very heavy yields may be obtained, though the sugar content is often low. On such soils the plant grows a high proportion of "top" to "root," hence small-topped varieties of high sugar content are here to be preferred, whereas on sandy loams a strong growing variety with large tops will yield more sugar per acre.

Sugar beet is always grown on contract for the factory which is ultimately to handle it. As the grower is responsible for delivering the beet to the factory, which he does either by rail, road or water, the distance to the nearest factory is an important consideration. Another factor in choosing the fields on which sugar beet shall be grown is their proximity to a hard road. The carting of such a bulking crop long distances over soft tracks in wet weather is very expensive at best, and sometimes impossible.

The seed-bed for sugar beet should be very similar to that described for mangel wurzels. The field should have been cleaned in the autumn, farmyard manure applied, and finally well and deeply ploughed for the winter. Subsoiling is generally considered advantageous, particularly on soils which have a hard pan at or about the normal ploughing depth. It is very desirable to grow long well-shaped roots, as distinct from "fangy" misshapen roots, and subsoiling will assist in this.

The date of sowing is from the beginning of April until the middle of May. Frequently the area to be grown is divided into sections to be sown at two or three different dates, with ten-day intervals between them. This is so that the whole of the acreage should not come to the hoe at once. The early sowing should be some variety not subject to bolting. It is very important that the plants should be set out at an early stage in their growth preferably as soon as possible after reaching the four-leaf stage. Nothing is likely to reduce the crops more than to allow the plants to become too big before they are singled. During the early summer the plants should be frequently hoed.

Experiments point to the importance of the number of plants per acre. It would appear that 30,000 plants per acre is the ideal at which to aim. The common practice is to sow in drills from 18 to 22 in. apart, and to set the plants out to a distance of nine inches. In order to do this nothing bigger than a six-inch hoe must be used.

The usual quantity of seed to sow is from 15 to 17 lbs. per acre. As with mangolds, it is by no means easy to get a perfect plant, and in order to assist germination, particularly in dry weather, various devices are employed, such as the use of seed which has been treated with sulphuric acid in order to dissolve the seed coat. On most soils sugar beet requires liberal manuring. In addition to farmyard manure a generous all round dressing of artificial manures should be applied, this will often be composed of some such mixture as :—

2—3 cwt. Nitrate of Soda,
3 cwt. Superphosphate,
1 cwt. Muriate of Potash,

per acre, the whole being applied to the seed-bed before drilling.

After the sugar beet is harvested the tops are a valuable by-product. These, after they have been allowed to wilt for some ten days, make excellent food either for sheep or cattle. If the former, then the tops are folded off on the land on which they grew. The latter involves carting the tops off the land, an additional expense. When feeding tops to cattle it is always advisable to feed some ground chalk in the ration. If desired the "tops" can be ensiled in a clamp or pit silo, to provide feed at some future date.

Swedes.—These are the most valuable variety of the turnip family. The preparation for this crop is chiefly made in spring, and though the seeding commences in the early part of May in some districts, it is not begun until the second week in June, or even later, in many others. This is because the early-sown swedes are specially liable to attacks of mildew, when grown on soils which soon become parched in seasons of hot, dry weather. If swedes have grown rapidly, and then receive a sudden check, the mildew attacks them, and may utterly destroy them. The early-sown swedes suffer most in this respect, as they are less vigorous. When land is ridged, it is inconvenient to make the ridges of less width than about two feet three inches ; therefore it may always be understood that crops of roots drilled on the ridge are drilled that distance or more apart. On the flat, however, it is not uncommon to drill them as near as 18 in. from row to row, though two feet is the most common distance.

Swedes and turnips differ from mangolds in being shallow-rooted, and therefore require their food in a soluble form near the surface. Phosphoric acid is the ingredient they have the most difficulty in obtaining from the soil, so artificial mixtures used for the swede crop should consist largely of phosphates in some form or other.

Good crops of swedes and turnips can be grown with farmyard manure alone, but better results are generally obtained by using a moderate dressing of dung supplemented with some quickly-acting phosphatic manure, such as superphosphate of lime. Such a dressing would consist of some 10 tons of dung per acre, put on beforehand, together with three to four hundredweight of superphosphate sown at the time of drilling. It is to be remembered,

however, that in the north of England larger quantities of artificial manure are used for the root crop than in the south. In some arable districts, such as the Cotswold Hills, many acres of swedes and turnips are grown with artificials only, without any dung, and in such cases the usual dressing consists of some four hundredweight of superphosphate per acre, together with half to one hundredweight of nitrate of soda or sulphate of ammonia. Where the soil is naturally deficient in potash, from two to three hundredweight of kainit may also be allowed in addition.

Turnips.—There are several distinct varieties of turnips, and there are almost innumerable selections of these varieties, which are very similar in everything but their names. These can be sown so as to provide food from July to Christmas or later, if advantage is taken of the early maturing and frost-resisting properties possessed by individual varieties. If sown very late in the summer, they will resist frost, and throw up sprouts in the spring, which are very valuable as sheep or lamb feed in February and March. A good tilth is necessary, and the earliest varieties may be put in during April; but, for a main crop, May and June are usually the best months. Seeding may continue on the bastard fallows, and after green crops generally, until the middle or end of August. The stubble turnips, if sown at the latter date, are fit for feeding in the autumn. It is not an uncommon practice to sow the stubble turnips broadcast, but all early-sown varieties should be drilled in order to allow proper opportunities for hand-hoeing and horse-hoeing.

Carrots.—These roots grow best on light soils free from stones. If grown on heavy soils they are troublesome to dig up, and so much earth adheres to them that washing becomes tedious and expensive. As the young plants have very small tops, the crop is not suited to weedy land, for in cold seasons the weeds overgrow the carrots, so that it is practically impossible to separate them. A few oats are sometimes mixed with the carrot seed before drilling, as they help to show up the rows after germination. A fine tilth, prepared by the land being ploughed and dunged during autumn, and well stirred just before seeding, is necessary; and the seed should be drilled, in March or April, in rows from 12 to 18 in. apart. About six to eight pounds of seed per acre is required, and before sowing it should be well rubbed and mixed with dry sand or ashes, so that it will not clog in the drill, but will fall freely into the drill-rows. It should be harrowed in with light harrows, and not covered with more than an inch of soil. Carrots are particularly valuable as food for horses and dairy stock.

In some districts a small quantity of carrot seed is sown with the mangold crop, as the carrot will often stand where the mangold fails, and it grows well in association with mangold.

Parsnips.—These roots grow more freely than carrots, and though they require good preparation of the soil, their broader tops are better able to grow away from weeds. The seed should be drilled

in February and March, about six to eight pounds per acre, in rows a foot apart.

Subsequent Cultivation of Roots.—For this purpose the disc hoe is ideal (p. 55). The horse-hoes should be put to work as frequently as possible, until the roots get so big that the horses cannot walk along the rows without injuring them.

The manual labour consists of flat-hoeing—often dispensed with in the case of swedes and turnips—with a broad hoe alongside the rows, to clean such places as the horse-hoe misses, and of "singling," to set the plants out at regular distances, and to separate the plants so that there shall not be more than one standing together. Singling should commence when the plants have a width of about three or four inches across the leaves. The operation is rarely done perfectly at the first attempt, and it is usual for it to be done twice. Where the rows are placed about 18 in. apart, the plants may be left from 14 to 16 in. from centre to centre; on widths of two feet three inches, a space of 11 in. is sufficient. In some localities, roots are hoed into bunches, and afterwards singled by hand by women and children.

Harvesting of Roots.—Swedes are got up in the autumn for storage in the field where they were grown, or they are carted to the homestead. When stored, the roots should be carefully covered with a layer of straw several inches in thickness, and over this a layer of earth some few inches deep should be placed to keep out wet.

The mangold crop is harvested some time in October or early November, when the leaves turn yellow, as it is very susceptible to frost. The roots should be injured as little as possible in lifting to prevent bleeding, and the tops are either cut or twisted off. After remaining a day or two on the surface to dry, they are carted to the pit or clamp, where they are carefully stacked together, and then covered first with a layer of straw and then with a layer of earth to protect them from the weather during the winter. A ventilating shaft, consisting of a bunch of straw or a drain-pipe, should be inserted at a distance of every six or eight yards.

Sugar beet are harvested in October, November and December, the factory usually insisting that deliveries be equally divided over the three months of the "campaign."

It will be found that as a rule the yield of sugar per acre gradually rises to a maximum in November, subsequently decreasing.

The first operation consists in lifting the roots. They are too firmly fixed in the ground to allow of this being done by hand, hence some special tool is used, generally a beet-lifting "plough," to loosen the beet in the soil. They are then pulled by hand and knocked together to remove as much of the adhering soil as possible. The beet are next carefully topped, not only the leaves but the whole "crown" being removed. Finally the beet are thrown into small heaps to be loaded and delivered to the factory as opportunity occurs.

Turnips are not usually stored, as, being soft, they are easily

gnawed by sheep. When required for cattle they are pulled in the same manner as swedes.

Carrots must be dug with a fork, and stored in a similar manner to swedes.

Parsnips may be left in the land until required, as they withstand severe frost. They, however, must also be dug.

CRUCIFEROUS FORAGE CROPS.

Rape.—This is very similar in its management to turnips. Occasionally a small area is sown in March to provide early sheep-keep in July. This is generally left, after feeding, to produce a second crop in spring. There are two varieties, the Dwarf and the Giant. The Dwarf is usually grown on thin chalk and other light soils ; the Giant is more commonly grown in the Fens, where it is sown broadcast or drilled in June, and fed off in September. The greater portion of the Dwarf rape is grown on land which has carried an autumn-sown catch-crop, and is drilled in May and June, at the rate of about five pounds per acre, in rows 15 in. apart.

Kohl Rabi, Thousand-headed Kale, and Red and Green Cabbages.—These all belong to the same family, and are a very valuable addition to the green forage crops of the farm. The chief advantages they possess over turnips are that they are not so liable to turnip-sickness and allied diseases, they are less affected by drought and frost, they are very nutritious and rarely upset the health of young animals, and they may be eaten at any stage of their growth with impunity. They also not only stand transplanting, but grow more freely as a consequence, thus affording longer time for the fallowing operations. Being in the first place grown in small compact seed-beds, they are more under the control of the grower, who is able to defend them from insect attacks with greater success.

TRANSPLANTING.—When cabbage, thousand-headed kale, and kohl rabi are raised in seed-beds, they may be transplanted at various times, so that a supply of green fodder is available without intermission throughout the year. The seed-beds should be sown in March, April and May to produce plants for transplanting through summer, and in August for autumn and spring transplanting. Kohl rabi should be grown in the spring seed-bed only, the other varieties may be grown in the autumn seed-bed also. By transplanting cabbages and kale from the autumn beds, a supply of green food may be relied upon to be fit for feeding from July to Christmas. Kohl rabi from the spring beds, transplanted in May and June, is fit for feeding from December to March , kale transplanted in summer is at its best from March to June. The cabbage tribe flourishes particularly well on heavy land. The seed-beds should be carefully prepared, as a fine tilth is necessary, and the seed should be harrowed or raked in lightly.

When plants are transplanted they are set out at various distances, according to the land and the variety of plant. Small early cabbages may be placed out at a distance of two feet apart in each

direction ; drumheads and red cabbages are best planted from two feet six inches to three feet apart.

The above crops may also be drilled in the field in the same way as turnips, and afterwards thinned out with the hoe to the required distances apart. Thousand-headed kale can in this way be sown in March or April for use from October to March, and in August for late spring and summer feed. Drumheaded cabbage is often drilled in the spring for late autumn and early winter use.

White Mustard.—This is frequently grown as a catch-crop during summer, with the object of providing green food for feeding off towards autumn. Some 15 lb. of seed per acre are generally sown broadcast after a fine seed-bed has been prepared.

LEGUMINOUS FORAGE CROPS.

Vetches or Tares.—These are sown principally with the object of providing keep for sheep, and green fodder for cattle and horses in spring, although they are sometimes taken as a crop for seed. They generally follow a white straw crop of some kind, and in light land districts they are often grown as a catch-crop between two main crops in the rotation. There are two varieties, " the Winter " and " the Spring," the former of which is sown in the autumn and will stand the winter. By sowing at suitable intervals a succession of green food can be arranged on the farm for a large part of the year. The preparation of this crop is simple, a piece of corn stubble being ploughed after a dressing of farmyard manure has been applied and spread. The seed can then be broadcasted and merely harrowed in, or the land can be harrowed down first and the seed afterwards drilled at the rate of two to three bushels to the acre. When broadcasted rather more seed is generally used.

The crop, when ready, is generally folded off with sheep, the autumn-sown crops usually being fed off in May, and the spring-sown later in the summer, according to the date of sowing. When grown for seed the crop is cut and harvested in a similar manner to peas.

Trifolium or Crimson Clover.—This is sown in the autumn as a catch-crop for spring and early summer keep. The cultivation is more simple than that required for any other crop, a corn stubble after harvest being merely well scratched with the drags, the seed then broadcasted on the surface, harrowed in, and finally rolled. No advantage is gained by a more thorough cultivation for this crop, as, although it requires a fine seed-bed on the surface, it likes the land quite firm and tight underneath. Ploughing, in fact, would have an injurious effect on this crop by rendering the soil much too loose, so that it would be impossible to get an even plant.

Lucerne.—The cultivation of this plant has increased considerably during recent years. It is a valuable crop on many soils, especially dry calcareous loams, such as those overlying the chalk, where, owing to its deep roots striking into the interstices of the

subjacent rock, it is able to obtain moisture, and throw up abundance of green food in a dry season. It does not do so well on soils where the subsoil is stiff and inclined to be wet.

Lucerne is sown either by itself or with a corn crop, with the object of remaining down a number of years. The best results, however, seem to be obtained where the crop is sown alone. Whichever way the crop is sown, the land chosen for the purpose should be in good condition, and a fine seed-bed should be prepared which is free from weeds. On soils in districts in which the crop has not been grown previously it is advisable to inoculate the seed before sowing (p. 403). The seed is best drilled in rows at about a foot apart, so as to give an opportunity of cleaning the crop during its growth, for without hoeing the plant soon gives place to weeds. It is sometimes the practice to give an old lucerne ley a sharp harrowing in the winter with the heavy harrows, and this rough treatment seems in many cases to benefit the crop by stirring the soil around the roots. Lucerne is generally cut green for soiling, and after it is established several cuttings may be taken during the summer. The number of years a lucerne ley will stand will depend upon the length of time it can be kept free from weeds, which will eventually grow up and smother it. It must then be broken up.

Sainfoin.—This is a crop of great importance to the flockmaster, especially on limestone soils, such as are found on the chalk and oolitic formations. It is very similar in its habits and cultivation to lucerne, and also, owing to its deep roots, it is able to resist drought It is generally sown about April with a corn crop following roots fed off with sheep. Importance should be paid to having the land quite clean before the seed is sown, otherwise there is a chance of the young sainfoin being choked by weeds.

The seed is commonly drilled in the husk in the "rough" or "unmilled" state, as it is called, at the rate of about a sack or four bushels to the acre Sainfoin is usually cut for hay the year after the corn crop is cleared, and the method of securing the crop is the same as for clover hay. There are two varieties of sainfoin, the "Common," which is used for long leys, and the French or Giant variety, which is short-lived and only lasts two years.

Sainfoin leys are generally allowed to remain down from five to seven years, in some cases longer, the length of time being determined by the growth of weeds, which, as in the case of lucerne, finally get the mastery.

Land which has recently grown sainfoin seems, in some peculiar way, to become heartily sick of the crop, and it is impossible to grow it again successfully on the same soil till a number of years have elapsed.

Sainfoin is a most valuable crop to wean lambs upon, and in certain summers, when the lambs do not seem to make headway on any of the other forage crops of the farm, and they are troubled with scouring, a change to a sainfoin ley will often have a beneficial effect, and they will begin to pick up in condition and lay on flesh.

Both lucerne and sainfoin are crops more particularly suited to the warmer and more genial climate of the south of England.

Trefoil, Yellow Clover, Nonsuch, or Black Medick (*Medicago lupulina*).—This is a plant that will grow on almost any soil, but is specially suited to poor soils in dry climates. It is therefore commonly grown in mixtures of grasses and clovers on thin limestone soils, but on some of these soils, where it is indigenous it assumes the character of a weed.

Clovers and "Seeds."—Clovers, and mixtures of clovers and grasses intended to take a place in a rotation, are almost always sown in amongst cereal crops, very often at the same time that the corn is sown, but occasionally after the corn has made some progress in growth. On the other hand, they are but rarely sown on land which is not to carry a corn crop concurrently with them, for "leys," or "seeds," as they are commonly termed, require to be on the land a full year before they are fit to feed. Although there is occasionally, during the first year, some little growth which may be fed, yet it is not sufficiently reliable for the crop to be sown with that object in view. The most common clovers grown in rotation are red or broad clover (*Trifolium pratense*), cow-grass (*T. pratense perenne*), white or Dutch clover (*T. repens*), alsike (*T. hybridum*), and trefoil (*Medicago lupulina*). All these are sown in one and the same manner.

Seeding.—When sown in wheat, barley, or oats, which have appeared above ground, "seeds" may be broadcasted on the surface with a seed-barrow, and are then harrowed in very lightly with the lightest seed-harrows, or with a horse-rake. The horse-rake is preferable on loose land, as it can be set so that too much of the surface soil is not disturbed, thereby preventing an excess of earth being thrown upon the seed, which cannot successfully germinate if buried to a greater depth than about half an inch. The harrows are most useful when the land is firm, as is frequently the case where wheat is being grown. The seed may also be drilled with a light seed-drill, greater regularity of germination being secured than by broadcasting. But, as the plants stand thickly in rows, they have not quite so good a chance of growing at subsequent periods, for they crowd one another. When drilled with a small coulter drill, "seeds" are best rolled in.

The seeding of clovers is often effected before the cereals are up, and they are then harrowed in during the final harrowing of the barley or oats. This is not always advisable, as sometimes the land "caps," or forms a hard surface on the top, which is injurious to both the corn and the clovers; and when the clover has germinated it is impossible, without destroying it, to stir the land For this reason it is most usual, on wet land, to sow the clovers just as the barley is appearing through the soil. Where the land is much troubled with annual weeds it is wiser to postpone the sowing of the clovers until the corn has been hoed, and the usual custom in such cases is to sow the seed shortly before hoeing, so as to cover it in

during the process of hoeing, harrowing being then unnecessary. When rye grass or other grasses are sown as a mixture with clovers, the seeding is often effected in two operations, in order to avoid undue proportions of seed in different parts of the field. This is, indeed, necessary when the seeds are drilled with a brush-drill, or sown with a seed-barrow, but not when they are put in with a cup-drill.

When land is too frequently cropped with clover it becomes clover-sick, and is unable to carry the plant to maturity, as the crop dies off during autumn and winter. Its destruction is due either to a fungus (*Sclerotinia trifoliorium*) (p. 378) or, not uncommonly, to an eelworm (Tylenchus). A deficiency of lime and potash is conducive to clover-sickness; therefore, where there is reason to believe that these substances are lacking, they should be applied in the most convenient form in which they can be obtained in the locality. The surest method of preventing the disease is to refrain from growing red clover too frequently. This is best arranged by forming a sub-rotation of clovers in the general rotation. Thus, if red clover is taken in its proper position in the rotation, but cow-grass or white clover is sown in its place four years after, and alsike grown four years later, then red clover again four years subsequently, red clover will only be on the land once in twelve years, and a plentiful supply of sheep-keep will be provided with less risk of clover-sickness. In some localities a mixture of alsike and white clover is sown when red clover is omitted.

After Management.—The after-management of the "seeds" crop is very simple. If the land is loose it is necessary to compress it in the autumn, by means of rollers, or by the treading of sheep; but "seeds" must not be fed too hard with sheep at that season. Sheep are the most perfect compressors of the soil, as they pinch the mould around the roots, whereas other forms of pressure are usually applied in broad sections, which cannot fit into the inequalities of the land. Sheep should not be put on heavy land in a wet autumn; but it is not often that clovers and "seeds" require consolidating during such seasons. The "seeds" should be rolled in the spring, and, if it is intended that the crop should be converted into hay, loose stones should be picked off the land, or they will prove troublesome at hay-time.

CULTIVATION OF POTATOES.

Potatoes are a field crop of considerable importance in certain counties, such as Cheshire and Lincolnshire, parts of Yorkshire and Lancashire, and also in certain districts in Scotland and elsewhere. Although potatoes are often referred to as a "root crop," they are not roots at all from the botanical point of view, but the tubers are enlargements of underground stems, which are stored with reserve food materials, to be used in carrying on future growth. Fresh plants are obtained by a vegetative growth or development from

the buds, or eyes, contained in the tubers, and thus the potato differs from other farm crops which reproduce themselves by a process of fertilization and the formation of seed. The potato, however, makes a fresh start each year from the tuber, which is really a portion of the old plant that has died down the preceding year. For this reason a new variety of potato generally begins to lose its vigour after a few years' growth, as is shown by a falling off in the yield and the crop becoming more susceptible to attacks of the potato disease (*Phytophthora infestans*). Suitable changes of seed from time to time, as regards soil and climate, will help to prolong the life of a variety, but on an average this does not last more than from twelve to twenty years, and often less. Taking the above considerations into account, it is of importance to the grower to discover which varieties of potatoes are best suited to any particular soil and district, and thus to increase the productiveness of the crop. Potatoes may be divided into early, second-early or mid-season, and late, according to the time they are ready to harvest. One of the most profitable branches of potato culture is that of growing early potatoes, provided they can be got ready very early in the season before the great glut of new potatoes from abroad and elsewhere floods the markets of the United Kingdom. Certain conditions, however, are necessary to be successful in the cultivation of early potatoes. One of these is a suitable climate, free from late spring frosts; another is a deep, warm, well-drained friable soil, capable of being heavily manured. Methods must also be made use of to hasten the growth of the crop, such as putting the seed tubers into shallow trays or boxes, and allowing them to sprout previous to planting. In this way a growth is taking place in the box before the tuber is planted, and thus the grower can afford to wait a week or two longer for suitable weather before planting out in the field. A good deal of care and judgment must be used with regard to the regulation of light and temperature in the building in which the boxes are stored; the object being to obtain strong, vigorous green shoots on the potatoes which will not easily break off. If the boxes are kept in the dark and at too high a temperature, long, weak, spindly shoots will be produced, which easily break off. Exposure to light and reduction of temperature will counteract this tendency. Without the above necessary conditions the growing of early potatoes will be a very precarious business.

Potatoes flourish best on deep loose friable soils, such as the lighter loams, especially when they contain a fair amount of organic matter. Poor sandy soils, if heavily manured, will grow good crops, provided there is a sufficient rainfall, and even heavy clays, if suitably treated, may be made to grow them successfully.

Big crops are often obtained from recently broken up grassland, and the potatoes seem to revel in the mass of decaying vegetable matter derived from the old turf. Some of the choicest potatoes are raised on the old red sandstone and the marls and sands of the trias; those grown on the greensand are generally of good quality,

and most of the light, mixed, gravelly loams produce high-class tubers. The rich fens and warp deposits yield immense crops, very good for change of seed, but the quality for eating purposes cannot be depended upon. Some heavy soils grow fair crops of potatoes, but as a rule these are not suited to strong clays with retentive sub-soils, and it is often almost impossible to dig them on these soils in a wet autumn.

The question of cultivation is a matter of very great importance. Although the methods may vary somewhat in different districts and on different classes of soil, there are a few points which are essential everywhere. In the first place, the land must be thoroughly worked to a good depth, and it is necessary that the crop should be moulded up two or three times during its growth. Where grown as a field crop, potatoes, as a rule, take the place of roots and follow a grain crop of some sort, often oats. The land may be ploughed lightly in autumn and worked so as to remove any couch near the surface, but in any case it should receive a deep ploughing before the end of the year, so that the furrow may be exposed to the beneficial action of the winter's frost. It may be necessary in some cases to plough again in spring, but this will all depend upon circumstances and the state of cleanliness of the land. Farmyard manure may be applied in the autumn before the winter ploughing, or may be spread in a short or rotten condition in the furrow in the spring. This latter method is generally followed on light sandy soils with porous sub-soils, where there is a fear of a large proportion of the manure being lost by washing into the sub-soil if applied too early.

Potatoes are grown on the ridge or on the flat, in the same manner as roots. When on the flat the rows are generally 20 to 30 ins. apart, and a distance of 12 to 18 ins is allowed between the sets; on the ridge the distance from row to row is 24 to 30 ins. and the sets 10 to 15 ins., according to variety.

The method of planting on the ridge is generally adopted in the damper climates of the north and west and on the heavier soils, whereas the flat system is more often followed on the drier soils of the south and east where the rainfall is less.

The preparation of the seed-bed is similar to that for roots. When growing on the ridge, the land, after it has been deeply worked and sufficient mould has been obtained, is set up in ridges, as soon as the ground is dry enough in spring, by means of the double-breasted or ridging plough. The manure carts then follow, and the dung, in a rotten state, is thrown out into small heaps, which are afterwards teased out by means of forks along the furrows. Any artificial manure used is then generally sown over the dung, and the sets are then placed in the furrow at the required distances apart. After this the double-breasted plough splits the ridges, thus covering up the seed sets and the manure, and enclosing them in the centres of the newly-formed ridges.

When grown on the flat the potatoes may either be ploughed in, the seed tubers being set in every third furrow and then covered

with the ordinary plough, or the system of "holing in" with the spade may be adopted, in which case the land is first reduced to a tilth. In this latter case the land is marked out in lines across the field, and a man with a spade makes holes at regular intervals along the rows, a boy who accompanies him dropping a potato into each hole as it is opened. They then return, the man making holes on a line parallel to the first, and as he does this he fills in the previous holes so as to cover the potatoes; in this way the whole field is planted. Potatoes may also be planted by dibbling them in. The dibble is a thick stick pointed at one end, with which holes are made in the ground, the potatoes being dropped into the holes and afterwards covered with earth.

During its growth the crop must be kept clear of surface weeds by means of continual hand-hoeings and horse-hoeings, and it is often advisable, especially when growing on the ridge, to commence by running the light harrows over the surface, so as to break any crust which may have formed, and also to destroy annual weeds.

When the tops are some 8 to 10 in. high, it will be necessary to earth up the rows by means of the moulding plough, and this will also have to be done a second, and perhaps even a third, time during the summer.

The selection of seed is a matter of great importance (*see* p. 162).

With regard to the best size of seed to use, medium sized sets which will pass through a 1¾ in. riddle, but not through a 1½ in., will be more profitable to plant than either very large, or very small ones, although large sets will give a better yield.

It is usually the practice to cut large seed-tubers, at least two eyes or shoots being left on each set. The results of recent experiments, however, tend to show that there is not much difference in the yield between planting whole and cut sets, when the same weight of seed is used per acre. It is a mistake to cut early and white-blossomed varieties, as these potatoes are more delicate and liable to decompose when cut.

The usual time of planting is from March to the beginning of May, according to the season. The early varieties should be planted first, the second-early next, and the main crop last.

From 12 to 15 cwt. of seed, according to the size, is the amount usually required to plant an acre, although in the potato-growing districts the quantity of seed used per acre is often greater than this. Potatoes are a surface-feeding crop, and require a liberal all-round manuring, containing the three essential ingredients—viz., nitrogen, phosphoric acid, and potash—to ensure an abundant yield.

MANURING.—Good crops may be grown with artificials alone, without dung, especially after "seeds" or an old turf, but a dressing of farmyard manure is generally considered necessary for the early varieties.

Potatoes require plentiful supplies of potash for their starch development, and where a mixture of artificials is used it should contain a fair proportion of some potassic manure.

When large dressings of dung are employed artificial manures are not essential, but it is now considered more profitable to use a moderate dressing of dung—say, 12 to 15 tons to the acre—and supplement it with a complete mixture of artificials (p. 162).

CHAPTER X.

SEED RATE AND SOWING.

In the chapters on farm crops are given typical methods of sowing. These are necessarily the normal methods followed under average conditions. Now average conditions are purely hypothetical. Between district and district, field and field, season and season, and in the many other circumstances affecting crop production, there are wide variations. It is largely by ability to understand these and to modify practices accordingly that the successful farmer is distinguished. No words can describe the many and subtle variations which influence the practices involved in sowing. They become known only by experience. But certain principles have emerged from accumulated farmers' experiences and from investigations and it is with these this chapter deals. For the student there are some cardinal points with which a study of seed rate and sowing should commence.

There are usually a number of somewhat different, practicable, ways of getting any crop sown. In other words, sowing is flexible and offers scope to enterprise. It is not always from the most elaborate procedure that the best results come. Probably one of the simplest of sowings is that employed by Arabs for wheat in parts of Iraq. After the first rain, at the end of the long "hot weather," the soil in large, shallow, natural depressions, becomes a network of cracks. Wheat is dropped by hand into these cracks. The second fall of rain covers it in and sowing is completed.

In the special circumstances no better—and in any circumstances no lazier—method could be employed. Occasionally in England, extremely simple wheat sowing is practised on very heavy, wet soil. An old clover ley may be broken by steam ploughs; the drill follows close behind travelling in the direction of the furrows; then come the harrows in the same direction. What was an 8–10 acre old ley in the morning is by the evening a wheat

field. Here again is an interesting example of modifying normal practice to meet special circumstances, among which are financial straits and the difficulty and often the undesirability of actually tilthing really heavy land for winter corn.

To wrest from any field the full crop which soil and season make possible, it is essential to ensure a full and even plant. Recent experiments, which will be described in a later passage, have given definite proof of this. Now from these same experiments it is clear that a full and even plant depends, with most crops, primarily on the seed and the operations involved in sowing.

Sowing is, indeed, the crop's start in life. Once the seed is in, relatively little can as a rule be done to improve the physical condition of the soil. Moreover, it is the circumstances of sowing which control early growth and this in turn largely predetermines the whole future development of the crop. In one series of experiments on wheat the seeds were carefully sown by hand in holes made at regular intervals by a special sowing iron. The life-long history of every plant was recorded. Some 80 per cent. of the seed germinated in a 3-day period (about 21 days after sowing), the remaining 20 per cent. germinated at intervals during a period of 14 weeks after the before-mentioned 3 days (most of them germinated in the first 10 days of the 14 weeks). Observations were made periodically throughout life upon rate of growth, upon leaf formation and upon tillering. Without exception the plants from late germinating seeds were less developed at every observation period than the others, and at harvest their average yield was only 65 per cent. of that of the others. Thus the loss in potential yield associated with late germination was about 7 per cent. on the whole crop. From such a loss on carefully managed plots we may probably infer that in the field the sacrifice is 15-20 per cent. of the full potential yield.

Now these later germinations were brought about partly by seed defects (discussed below) and partly by locally bad sowing conditions. It follows therefore that in seed and sowing lie some of the secrets of high yield.

Farmers work for profit. In choosing seed and deciding upon sowing procedure, therefore, the criterion must always be the effect likely to be produced upon the net monetary return per acre.

Success in sowing depends upon the seed and the seed rate; upon the inherent properties of the soil; upon the preparation of the seed bed—and into this the timing of operations largely enters; and upon the mechanical perfection and skilful use of the drill. We must discuss these factors, but it may be helpful if we first make a broad survey of the sowing of the common crops.

To the beginner it is very confusing to read, for one crop after another, the details of seed rate, time of sowing, depth of sowing, etc. It will assist him to consider the broad facts into which these details condense. For this purpose Table I. has been prepared :—

TABLE I.—SOWING DATA AND [illegible]

Crop.	Time of Sowing	Time of Harvest	Seed Rate per Acre.	Weight of 1 bushel of Seed	Yield per Acre.	Distan[illegible] apart o[illegible] Row[illegible]
WHEAT:						
Winter varieties	Oct.-Dec.	Aug.	2-3 bush.	63 lb.	32 bush. grain 30 cwt. straw	7"—9"
Spring varieties	Feb.-April	Sept.	3-4 bush.			
BARLEY:						
Winter varieties	Oct.	Aug.	2½-3 bush.	56 lb.	33 bush. grain 23 cwt. straw	7"—9"
Spring varieties	Feb.-March	Sept.				
OATS:						
Winter varieties	Oct.-Nov.	July-Aug.	2½-3 bush.	42 lb.	34-40 bush. 27 cwt. straw	7"—9"
Spring varieties	Feb.-April	Aug.-Sept.	3-5 bush.			
RYE:						
Winter varieties	Sept.-Oct.	July-Aug.	2-3 bush.	54 lb.	25-30 cwt. grain 35 cwt. straw	7" 9"
Spring varieties	Feb.-March					
For feeding off	Aug.-Sept.	April-June	4 bush.	54 lb.	—	
BEANS:						
Winter varieties	Oct.	Aug.	2-3 bush.	63-66 lb.	30 bush. grain 25 cwt. straw	20"—
Spring varieties	Feb.-March	Sept.	3-4 bush.			
PEAS (Field)	Feb.-March	Aug.	2-3 bush.	63-65 lb.	30 bush. seed 20 cwt. straw	20"—
VETCHES (= Tares)[1]						
Winter varieties	Oct.	July	3-4 bush.	64 lb.	25-30 bush. seed 25 cwt. straw	7"—1
Spring varieties	Feb.-March					
SAINFOIN[2]						
Giant	late March and April	July	4 bush. unmilled 1 bush. milled	30 lb. unmilled 60 lb. milled	30 bush. seed (unmilled)	7"—1
Common						
LUPINS	April	Aug.	1-2 bush.	62 lb.	20-30 bush. (seed crop)	15"
CRIMSON CLOVER	Sept.-Oct.	Late spring and early autumn.	20 lb.	60 lb.	8 bush. (seed crop)	7"—9"
KIDNEY VETCH	March	July-Aug. (for seed)	16-20 lb.	60 lb.	7 bush. (seed crop)	10"—
LUCERNE	April	June onwards.	20-24 lb.	60-62 lb.	8 bush. (as a seed crop) 8-15 tons (as a green crop) 2-3 tons (as a hay crop)	7"—1(
TREFOIL (= Black Medick)	April-May	June onwards.	15 lb.	60 lb.	7-8 bush. (seed crop) 10 tons (green crop)	7"—1
RED CLOVER (as a seed crop).	March-April	June (feed) Sept. (seed)	16 lb.	65 lb.	8 bush. (as seed crop) 2 tons (as hay).	7"—9
MANGOLD	Late April and early May	Nov.-Dec.	7-10 lb.	21 lb.	50 bush. (seed crop) 20 tons (feed).	21"—
SUGAR BEET	Mid April to early May	Nov.-Dec.	15 lb.	20 lb.	8 tons (roots) 5-7 tons (top).	16"—
MARROW STEM KALE	April-May	Nov.-Dec.	4 lb.	54 lb.	4 bush. (seed crop) 15-25 tons (feed)	24"—
THOUSAND HEAD KALE	March to early June	Nov.-Feb.	4 lb.	54 lb.	4 bush. (seed crop) 12-20 tons (feed)	18"—
RAPE (= Coleseed)	Throughout Spring and Summer	October to April according to sow'g time	5-6 lb. (drilled) 6-8 lb. (broadcast	50 lb.	30 bush. (seed crop) 10 tons (feed)	12"—
CABBAGE[10]	March	Nov.-Dec.	4 lb.	53 lb.	20 bush. (seed crop) 20 tons (feed)	24"—

Crop	Time of Sowing	Time of Harvest	Seed Rate per Acre	Weight of 1 bushel of seed	Yield per Acre	Distance apart of Rows
HL RABI[11]	March-April	Oct.-Nov.	4-5 lb.	54 lb.	4 bush. (seed crop) 20 tons (feed)	20"—30"
RNIP[12]	July	Oct.	3-4 lb	50 lb.	20 bush. (seed crop) 15-25 tons (feed)	18"—24"
EDE[12]	June	Nov.	4-5 lb.	50 lb.	16 bush. (seed crop) 12-18 tons (feed)	18"—24"
JSTARD[13]	April	Aug.-Sept.	12-14 lb.	54 lb.	12-25 bush. (seed crop)	12"—18"
JCKWHEAT (= Brank)	Late May	Sept.	1½-2 bush.	50 lb.	20-30 bush. (seed crop)	7"—10"
NSEED (for seed)	Late March and April	Aug.	1-2 bush.	52 lb.	15-20 bush (seed) 20-30 cwt. (straw)	8"—10"
TATOES[14]	March and April	late June to Oct.	15 cwt.	54 lb	6-8 tons	20"—24" (early) 24"—28" (maincrop)
AIZE	Mid-May	Sept.	1-2 bush	60 lb.	20-25 tons (feed)	20"—24"

Note.—True winter varieties are 6-row barleys. In the South spring malting varieties are often sown)ctober.

[1] The data above is for vetches grown for seed. They are also sown similarly for folding, autumn sowings ıg ready in May and spring sowings during July and August, according to date of sowing. Further, vetches , be grown for hay: they give about 30 cwt hay per acre and should be cut when in full flower. See e 7.

[2] The straw from a seed crop of sainfoin is worthless for feed, being entirely hard stems. Sainfoin is ally sown under a cereal crop. It may be sown, as above, for hay, giving 30-40 cwt. of hay per acre. ting for hay should be before the crop flowers. Giant sainfoin gives two hay cuts a year but cannot fitably be left down more than two years. Common sainfoin gives one hay cut per year, and the aftermath be grazed. It remains profitable for 5, 10, or even more years. See also Note 7. In growing seed a hay p may be taken first, the plant then remaining for seed.

[3] Crimson clover is usually sown in autumn on a stubble. It is sheeped in spring or cut for green fodder: aftermath also affords a light grazing. See also Note 7.

[4] In some districts September sowings are successful. Ordinarily, spring sowings are under a corn p but many growers favour broadcasting. Two cuts may be taken in the first year, *i.e.*, the calendar year r sowing: three cuts are possible in subsequent years and the crop often remains profitable up to the enth or even tenth year, if kept clean. See also Note 7.

Trefoil is usually sown under a corn crop. It may be kept down for a second year if a good plant be ablished. It is the first of the leguminous fodder crops to become available. See Note 7. Sometimes seed own in the cosh (pod). This is safe if the soil is sufficiently moist to ensure germination. A heavier i rate is, of course, required (*e.g.*, 50 lb.)

Both types of red clover—broad-leaved and late flowering (= single cut cow grass)—are usually mixed h grasses when sown for feed or hay. They are sown under a corn crop. When grown for seed they may used for sheeping also. Broad-leaved clover may be cut for hay or heavily sheeped in May and then left seed. But the late flowering type if first cut for hay is so late in flowering that little seed is set. It may, wever, be lightly sheeped in April (not later) and then left for seed.

The order of availability for grazing of the common leguminous fodder crop is usually: winter vetches st), trefoil, lucerne, broad-leaved red clover and sainfoin, late-flowering red clover, spring vetches.

For a seed crop, sowing is in July, in rows about 12 inches apart and at 20 lb. per acre. The plants lifted and planted out in the same field in February or early March in rows at 28 in. and at 12 in. in the Alternatively seed may be sown in July in the manner adopted for ordinary sowings of mangold and to grow to seed. It is cut by hand in September.

One acre of beet tops will feed 100 ewes for one week, there being available also, a suitable grass run.

[10] The data here is for a crop treated like a root crop for a variety such as the Ox-drumhead. This variety y be sown in a seed bed in August and transplanted in April or May. It is then available for feed from late gust to October. Earlier varieties like Winningstadt, sown in March, are ready for use in November. r late winter and early spring use, a hardy variety like Ormskirk savoy, sown in March, may be used. r transplanting, 1-2 lb. of seed sown in 2 square rods is sufficient to plant 1 acre.

[11] Kohl Rabi may be transplanted similarly to cabbage (see Note 10). The crop is usually folded off t may be carted and stored temporarily. There are two main types: the small top which is suitable for October ding and a hardier large top type which may remain for folding after Christmas. This latter type is hardier in swedes.

[12] In the North and in Scotland turnips and swedes are sown about a month earlier than the dates given re which are for the eastern and southern counties of England. The row interval is small (18 in.) on light id, but where crops are heavy may be as much as 27 in. The yield of both crops is largely determined by infall, being light in the drier areas. One acre of good turnips will keep 100 ewes for 2-3 weeks.

[13] The data here is for white mustard but applies approximately to brown mustard also. White mustard often grown in the southern and eastern counties for folding. About 20 lb. of seed is drilled or broadcast r acre and the crop may be eaten off in 6-8 weeks after sowing which may take place at any time between ril and August.

[14] The treatment of potatoes varies widely as between districts and as between early, second, and aincrop varieties. The data here given are merely representative.

The data are drawn partly from text books and partly from experience on various farms. Emphasis must again be placed upon the fact that in practice endless variations are met. Take the case of wheat. The table contemplates the following circumstances: a winter variety may be sown in October at 3 bushels per acre and may yield 32 bushels of grain. But the same variety might be sown in mid-December at 2 bushels per acre, yielding 60 bushels. No table of this kind can hope to do more than acquaint a beginner with reasonably representative facts which serve, among other things, to help him to compare the various crops. Data for yields and harvest times lie outside the scope of this chapter, but are added to make Table I. a more complete source of reference.

The first general feature to study is the grouping of the crops. It will be seen that in many features wheat, barley, oats, and rye are similar in respect of seed rate, sowing dates, and the other data of the table. Common clover, lucerne, trefoil, and red clover are another group. As a first step the beginner should break up the crops into groups for himself. He will find that similarity depends upon broad botanical relationship coupled with seed size (average weight of a seed). At this point it is helpful to turn for a while to Table II.

TABLE II.—The weight (grammes) of 1,000 seeds, the number of seeds per 1 lb., and the average germination per cent. of the common crop plants. (Data from samples submitted for test to the Official Seed Testing Station.) In the data of germination, "H.S." denotes "hard seeds." Germination percentages are based on 8-year averages for grasses and 12-year averages for all other crops. Weights are for "air-dry" seed.

CROP	Weight (gms.) per 1,000 seeds	No. of seeds per 1 lb. in 100's	Germination per cent.
WHEAT—			
All samples	—	—	95·8
Red Marvel	54·07	84	
Yeoman	45·51	100	
Little Joss	49·39	92	
BARLEY—			
All samples	—		95·5
Spratt Archer	46·15	98	
Plumage Archer	46·43	98	
OATS—			
All samples	—		
Black Tartarian	30·76	147	
Abundance	39·71	114	
Victory	40·48	112	
Grey Winter...	37·32	122	
RYE	27·83	163	91·4
BEANS (Field)	568·12	7·98	95·4

CROP	Weight (gms.) per 1,000 seeds	No. of seeds per 1 lb. in 100's	Germination per cent.
Peas—			
All samples	—	-	86·3
Maple	206·75	22	——
Dun	237·70	19	——
Vetches	60·68	75	89·7
Sainfoin—			
All samples	—	—	71·1
Milled	15·23	297	——
Unmilled	23·68	192	——
Crimson Clover	3·41	1,330	82·0 + 0·3 H.S.
Kidney Vetch	2·27	1,998	72·4 + 5·6 H.S.
Lucerne—			
All samples	—	—	82·7 + 5·9 H.S.
English	2·06	2,202	——
Provence	1·96	2,314	——
Trefoil (= Black Medick) ...	1·62	2,799	75·3 + 2·6 H.S.
Red Clover (English) ...	1·77	2,563	79·4 + 4·9 H.S.
Birdsfoot Trefoil	1·16	3,910	Variable.
Alsike	0·73	6,214	82·3 + 6·8 H.S.
White Clover—			
All samples	—	—	77·1 + 9·6 H.S.
Wild	0·56	8·099	——
Dutch	0·61	7·436	——
Suckling Clover	0·51	8,894	66·5 + 17·0 H.S.
Tall Oat Grass	3·20	1,417	77·3
Italian Rye-grass	2·13	2,130	82·0
Perennial Rye-grass ...	2·00	2,268	82·3
Cocksfoot	1·01	4,491	90·3
Tall Fescue	1·88	2,413	——
Meadow Fescue	1·85	2,452	83·9
Chewing's Fescue	0·79	5,742	70·9
Hard Fescue	0·79	5,742	75·6
Sheep's Fescue	0·79	5,742	——
Fine-leaved Sheep's Fescue	0·30	15,120	——

CROP	Weight (gms.) per 1,000 seeds	No. of seeds per 1 lb. in 100's	Germination per cent.
Meadow Foxtail	0·77	5,891	62·3
Crested Dog's-tail	0·46	9,861	78·3
Timothy	0·29	15,641	88·8
Golden Oat Grass ...	0·24	18,900	—
Meadow Grasses—			
Poa nemoralis	0·20	22,700	73·1
Poa pratensis	0·18	25,200	80·4
Poa compressa	0·15	30,239	—
Poa trivialis	0·14	32,399	86·6
Fiorin	0·07	64,799	
Mustard	5·36	846	82·5
Rape	4·24	1,070	87·6
Kale—			
All samples	—		79·1
Marrow Stem	3·75	1,209	—
Thousand Head	3·55	1,278	—
Cabbage	2·98	1,522	78·7
Kohl Rabi	2·85	1,592	76·1
Swede	2·83	1,603	93·5
Turnip	2·08	2,181	86·3
Mangold	19·33	235	76·0
Sugar Beet	23·13	196	82·1
Parsnip	4·53	1,001	61·4
Carrot	0·74	6,130	63·8
Buckwheat	23·63	192	
Linseed	6·78	669	88·0

Commercial samples of seed fluctuate so widely that great numbers must be examined to obtain reliable average values of seed weight, germination, etc. The only material adequate to this purpose is the vast array of samples submitted for test to the Official Seed Testing Station (part of the National Institute of Agricultural Botany, Cambridge). The Chief Officer of the Station has very kindly compiled Table II. from his official records and from an extensive series of determinations made specially for this

purpose. From the table general similarities in seed weight are readily apparent. It is important to note that crops with about the same seed weight necessarily have about the same number of seeds per 1 lb.

Having studied the general grouping of crops the student should next attend to the leading features of every group. The cereals will serve as an example. In all of them there are winter varieties sown from October to December (early November being the commonest time); there are also spring varieties sown in February, March, or early April. The corresponding seed rates are 2–3 bushels and 3–4 bushels per acre respectively. In all cases the distance between rows is 7–9 in. and the depth of sowing (see later for all crops) is 1¼–1¾ in. Now the differences must be noted. They lie mainly in average weight of a single seed (see weight per 1,000 seeds in Table II.) and there are corresponding differences in number of seeds per 1 lb. and per 1 bushel. Consequently the number of seeds sown per acre is by no means the same for all the cereal crops. Simple calculations will illustrate this. If wheat is sown at 2½ bushels per acre (with 63 lb. per bushel and 10,000 seeds per 1 lb.) there are 1,575,000 seeds per acre. With drill rows at 8 in. apart the total length of row per acre is 65,340 ft. (about 12½ miles). Thus the average number of seeds per foot of row is about 24 (for the importance of numbers of plants per foot see the concluding passages of this chapter). For winter oats (16,300 seeds per 1 lb., 42 lb. per bushel, and 2½ bushels per acre—see Tables I. and II.), the number of seeds per acre is about 1,711,500, *i.e.*, somewhat higher than for wheat as calculated above but of the same order.

Many interesting comparisons may be made between botanically dissimilar crops. Thus for wheat (as above) 1,575,000 seeds are sown per acre with rows at 7–9 in.; for sainfoin (milled seed) (1 bushel per acre, 60 lb. per bushel), 1,782,000 seeds per acre with rows at 7–10 in.; for winter beans (2½ bushels per acre, 64 lb. per bushel, 798 seeds per 1 lb.) about 127,680 seeds per acre with rows at 20–28 in. (average 24 in.). Thus for wheat about twelve times as many seeds are sown per acre as for beans but the total length of row per acre is about three times as great (viz. 24 in. : 8 in.). Hence about four times as many seeds per foot of row are sown for wheat as for beans. This difference corresponds to the marked difference in growth habit between these two crops.

The student should now make similar calculations for the other crop groups.

Variations in seed rate, *i.e.*, weight of seed sown per acre, are governed by many factors. Broadly speaking, all crops of about the same seed size and of similar growth habit, are sown at about the same rate. And, as between different crops, the smaller the seed (therefore the greater number of seeds per 1 lb.) the lower the seed rate. But for any one crop variations have to be made according to circumstances. As a rule the seed rate is increased above

the normal when late sowings are made. This is well illustrated in a recent study of sugar beet fields in the Eastern Counties :—

Amount of seed (lb.) per acre ...	Less than 12 lb.	12.0 to 12.9 lb.	13.0 to 14.9 lb.	Exactly 15. lb.	More than 15 lb.
Number of fields observed	18	16	19	21	20
Average date of drilling	5 May	5 May	11 May	11 May	14 May

Different varieties of the same crop may require different seed rates. Thus experienced growers of Rivet wheat normally sow 30–50 per cent. more seed of this variety than of the other common winter wheats. Recent experiments have revealed the facts upon which this practice rests. Rivet has a lower rate of germination and survival than other common winter wheats and tillers less abundantly. Consequently a denser plant population is desirable and therefore to sow at a rate considerably above normal is clearly necessary. Sometimes semi-hardy oat varieties (*e.g.*, Bountiful and Marvellous) or even spring varieties (*e.g.*, Abundance and Record) are winter sown. In such cases 3–4 bushels of seed is employed in contrast with the 2–2½ bushels which suffices with the true winter hardy varieties (*e.g.*, Grey Winter). For very large seeded varieties an extra seed rate is often employed as, for example, with oats (*see* Table II. for seed weights of varieties.) If severe damage by birds, wire worm, or other agency be feared, heavier seeding, it may be by as much as 50 per cent., is normally employed. The purpose for which the crop is required must also be taken into account. Cereals, especially rye, are sometimes grown for green feed and 4–5 bushels of seed, often sown broadcast, is then desirable. It is probably true to say that under-seeding is a more common error than over-seeding ; and further, that loss of potential yield often results.

Under-seeding rarely occurs through lack of knowledge. It is frequently traceable to bad seed or to a drill incorrectly set or imperfect in action. For broadcasting an increase in seed rate often of the order of 50 per cent. over the rate for drilling, is usually allowed.

Certain aspects of germination must be considered in connection with seed rate and sowing. All seed offered for sale must, under the Seeds Act, 1920, satisfy certain conditions as to purity and germination. But with cereals, farmers depend largely on home raised seed or purchase from their neighbours. There is in general no reason why this should be unsatisfactory. But at times, especially in wet harvests, seed may be of unusually low germination capacity. It is always advisable to have a test made. The Official Seed Testing Station offers special facilities for testing farmers' seed samples. The fee is sixpence per sample, and tests are completed and reports issued in the minimum possible time. If germination be low, *e.g.*, 80 per cent. for wheat instead of the normal 95–98 per

cent., the seed rate should be substantially increased. A sample which germinates rather badly in the laboratory is likely to germinate very poorly in the field unless conditions are extremely favourable. This is because the presence of any considerable proportion of non-germinable seeds always denotes the presence of many seeds which, while capable of germination in the laboratory, are physiologically so poor that they cannot grow in the field. In 1925, "good" and "bad" samples of certain wheat varieties were sown under typically "bad" field conditions on heavy clay. The data from one test illustrate the general principle :—

	"Good" Seed	"Bad" Seed
Laboratory germination, per cent.	99	80
Field ,, ,, ,, ...	65	32

In the light of laboratory tests the seed rate for the "bad" seed should have been increased in the proportion 100/80 = 125 per cent., but from the field data it is evident that to secure as full a plant as the "good" seed gave, the "bad" seed should have been sown at about double the normal rate. In some crops the disparity between laboratory and field germinations from a "bad" seed sample is particularly great. Peas and some of the grasses are familiar examples. Typical germination values of all common farm seed are given in Table II. Differences such as between cocksfoot and meadow foxtail are of great practical importance. Seed dormancy is sometimes a puzzling aspect of germination. Seeds of the Black Winter oat, especially from a wet harvest, may be six to eight weeks in the ground before germinating. Wild white clover, especially when sown in late summer or autumn, may be very tardy in germination. For the first year there may be an obvious paucity of clover plants in a newly-sown ley ; but during the second year an abundant plant may appear. Germination is only the first stage in establishing a plant and special attention may be required during seed bed preparation and sowing to ensure survival in the early stages following germination. Spring sown grass seed best illustrates this. If the seed bed be not firm below and dry weather follow germination, the seedlings, speedily exhausting their small endosperm reserves, die out. The seed, instead of growing, is simply "malted."

Cost of seed is sometimes allowed to be a factor in seed rate. While the farmer cannot afford to ignore any production cost, he is usually well repaid by purchasing good seed. By "good" is implied seed true to type, as free as possible from impurities of every kind, free from disease, and of high germination capacity. For special selections, new varieties, and other stocks of "pedigree" seeds, prices above normal are naturally charged. But "good" seed for ordinary sowings is not costly. To give the student information on prices of seed of common farm crops, the Eastern Counties Farmers' Co-operative Association, Ltd. (Ipswich) were asked to give representative quotations for 1930. They have kindly supplied the following :—

SEED RATE AND SOWING

CROPS.		Purity.	Growth. not less than
Winter Wheats	14/6 cwt.		90
Spring Wheats	14/6 cwt.		90
Barley	13/- cwt.		90
Oats	10/8 cwt.		85
Rye	11/- cwt.		80
Winter Beans	11/6 cwt.		90
Spring Beans	11/6 cwt.		90
Field Peas	12/- cwt.		80
Common Sainfoin	35/- cwt.	98	90
Giant Sainfoin	32/6 cwt.	98	90
†Trefoil	50/- cwt.	99·5	92 + 3
Kidney Vetch	50/- cwt.	98	90
Common Vetch (tares)	24/- cwt.	98	95
Lupin (Blue flowering)...	15/- cwt.	98	90
*White Turnip	1/6 lb.	98	98
*Swede	1/6 lb.	98	90
Sheep Cabbage	3/6 to 4/- lb.	98	80
Mustard	30/- to 35/- cwt.	98	94
*Marrow Stem Kale (Special Stock)	2/- lb.	98	90
*Thousand-head Kale	1/9 lb.	98	96
*Rape Kale	4/- lb.	98	97
Rape	50/- cwt.	98	94
*Kohl Rabi	2/- lb.	98	90
*Mangolds ... According to quality	1/6 to 2/- lb.	98	90 (clusters)
*Sugar Beet	1/- lb.	98	90 (clusters)
Maize (Virginian White Horse-tooth)	10/- per bushel.		
Linseed (Special Stock Blue flowering)	25/- per bushel.		
Buckwheat	56/- qr. of 3½ cwts.		

* Owing to the severe winter of 1929, most "roots" seeds were, relatively to seeds of other crops, doubled in price in 1930. Normal prices for these crops may therefore be taken as about one half of those shown here.

† The second figure gives percentage of "hard" seeds.

GRASSES AND CLOVERS		Per cwt.	Purity.	Growth.
Italian Rye-grass, French.	22 lb. per bushel	56/-	99	98
,, ,, Irish.	22 lb. ,, ,,	50/-	99	85
,, ,, English.	20 lb. ,, ,,	50/-	98·1	90
Perennial Rye-grass, Irish.	28 lb. ,, ,,	42/6	99	90
* ,, ,, New Zealand.	30 lb. ,, ,,	70/-	99·5	90
Cocksfoot, Danish		84/-	90	95
* ,, Indigenous Scandia		150/-		
,, New Zealand		90/-	99	90
*Rough Stalk Meadow-grass		168/-	90·2	90
Meadow Fescue, American		95/-	98·7	95
Sheep's Fescue		130/-	96	90
*Tall Oat-grass		145/-	90	85
Timothy, American		50/-	99·4	94
*Crested Dogstail, New Zealand		140/-	99	92
†Broad Red Clover, Suffolk		From 60/- to 75/-	99	90 + 5
*Single Cut Cow-grass, Suffolk.		,, 180/- to 220	98	90
.*Late Flowering Red Clover, Suffolk.		,, 180/- to 220/-	98	90
†Wild White Clover, Suffolk. (Guaranteed genuine and off old pastures.)		From 5/- to 7/6 per lb.	99	91 + 6
†Dutch White Clover (English grown)		from 140/- to 160/-	99	89 + 6
†Alsike, Canadian.		,, 85/- to 95/-	98	95 + 2
*†Giant Red Suckling (Suffolk grown) ...		160/-	99·6	90 + 6

* The prices of these seeds, relatively to others, were abnormally high in 1930, the year to which all these price quotations refer.

† The second figure gives percentage of "hard" seeds.

Movements in seed prices offer the student an important field of study, and he should make calculations of the proportion which cost of seed bears to total expenditure on production for the various crops.

In dealing with methods of sowing our concern here is to show how they influence plant development. The drills and other implements involved, their cost, rate of working, and adaptation to special circumstances, are dealt with in the chapters on Implements and Crops. Seeds are sown either broadcast or in rows. Broadcast sowing originated in hand casting, a procedure still occasionally employed and with much to recommend it. The "seed fiddle" and broadcasting machine, the latter in principle a seed drill without spouts and coulters, are the mechanical successors of the hand broadcaster.

Sowing in rows was brought to a high level of excellence in the use of the dibbing tongs or irons. Specimens of these are preserved as curios in many a farm house, and the older men on farms well remember their use for corn and for beans. A seed rate of even 1–3 pecks per acre often gave good yields. Biologically the merit of this method lay in the even spacing of the plants, the regular depth of sowing, and the even covering in of the seed. On experimental plots sown with a form of dibbing iron, the rows at 6 in. apart, the seeds at 2 in. in the row, yields at the rate of 45–55 bushels per acre of wheat and barley have often been obtained on land which, ordinarily cropped, gave but 30–40 bushels.

The slowness of dibbing inspired the invention of the seed drill of which there are many types. From the point of view of plant development in relation to yield, all drills are very defective. They do not sow at the same rate from point to point along any one drill row (*i.e.*, coulter row), the separate coulters deliver at different rates, and the seed is all deposited in a narrow band (*i.e.*, the "cut" made by the share of the coulter). Depth of sowing is also extremely irregular and, especially when sowing is on a rough tilth, while some seeds are suitably covered with crumb, some are left uncovered, and some overlain by large clods. In all these features drills are inferior to the old dibbing irons. From time to time efforts have been made to overcome these defects. A "force" feed has been tried in place of the cup feed, but on the whole it is probably less regular in delivery. Cross drilling, *i.e.*, drilling a field twice in right angle directions but at the same total seed rate per acre, has sometimes been adopted to give more even distribution of plants. With the same object in view experiments have recently been made at the Norfolk Agricultural Station by sowing barley with the rows at 3½ in. apart instead of the customary 7 in. Three years' results point to an increase in yield of some 7 per cent., which increase is, of course, clear gain. These modifications represent endeavours to secure more regular spacing of the plants. Advances are also being made at the present time by "spacing drills." These deposit groups of seeds at regular intervals in the row. They are

designed primarily for roots, especially sugar beet, and for market garden crops like cabbages, lettuce and onions. The groups of plants are thinned by hand to singles. With present models there is apt to be no mean way between groups so large that singling is very difficult and groups so small that from some no seed survives. But the spacing drill is in its infancy ; it is a sound conception, and it promises when improved to promote increased yields through better development of the individual plant. The ideal of plants at regular intervals and with no " misses " is examined and contrasted with actual crops in a general discussion at the end of the chapter.

While it is important always to have this ideal in mind, the difficulties of practice and the success which, under wise direction, attends rough expedients, must equally be remembered. In a wet year, on heavy clay it may at times be quite impossible to get a tilth for wheat, or to work a seed drill in the ordinary way. This difficulty has sometimes been met by removing spouts and coulters, letting the seed " spill " out from the drill on to the unprepared surface, and ploughing it in.

Of all sowing questions, the choice of time is perhaps most difficult. From the discussion of groups of crops, earlier in this chapter, it will have been perceived that there are recognised " times " of sowing for all crops which take the form of periods of some four to eight weeks. With crops like wheat, oats, vetches and beans there are winter and spring varieties which offer the possibility of two sowing periods in the year. There are other cases in which, with the same variety, the farmer may fairly safely make his choice of a somewhat early or a very late sowing. Thus lucerne may be sown in April–May, or left till September, and land may be put down to grass by under sowing corn in March April or, alternatively, by sowing on bare fallow in August-September.

There have been many experiments to ascertain the influence of date of sowing upon yield. Most of them have been on a small scale in pots or small hand-worked plots. While quite satisfactory as physiological investigations, they leave untouched the agricultural factors. The influences of time of sowing are twofold—agricultural and physiological. Compare two sowings of wheat on heavy land, the one in a wet mid-October, the other in a fine, early December. The October sowing will enjoy certain physiological advantages—and notably a higher temperature in the first few weeks after sowing—by which germination and early development will be favoured. But if, by December, the land is fairly dry in contrast with its suppositious extreme wetness in October, the later sowing will be on a much better seed-bed, for which reason, despite lower temperatures after sowing, it may yet make the better start in life. The subsequent relative progress of these two sowings will depend upon the combinations of weather factors that the particular year brings in its successive months. But the puddled seed-bed of the October sowing may have long enduring effects.

Broadly, from the farmers' point of view, it is wise to sow as early in the "sowing period" which experience has defined, as is consistent with good working conditions. There is always a strong element of uncertainty and therefore of risk, but the general tendency is to take the risk on the early side. Farmers may well conclude that the "right" time is "when you can get the seed in," but with some crops most careful consideration is necessary. Sugar beet, if sown unduly early, tends to bolt; if very late it yields badly. On a large farm with 100–200 or more acres of beet, sowing must for reasons of labour be spread over several weeks. To meet this necessity two or three different varieties are often grown. Sowing time varies much from district to district. This for turnip and swede sowing in the eastern and southern counties is usually a full month later than in the north.

The best depth of sowing in various circumstances is a consideration of much theoretical interest. In practice, however, it is governed by rules of a very general nature and will remain so until greatly improved implements increase our mechanical control over the soil. The chief variation made in sowing depth is as between one crop and another. Here the guiding principle is to adjust depth according to size of seed. Beans and peas are sown at 2–3 in., the cereals at about 1½ in., beet and mangolds at about 1–1½ in., and the "small seeds" (*e.g.*, clovers, turnips, etc.) at about ½–¼ in. Even on carefully made tilths there is great fluctuation. Thus in a field of wheat, the average depth may be 1½ in., but some seeds will lie at 2½–3½ in.; some will be on the surface but covered by clods, and some, lying uncovered, will be taken by birds.

Excessive depth of sowing is sometimes a fault. Wheat after fallow or after potatoes is a good example. The plumules of some of the germinating grains may have to struggle through 4, 5, or even 6 in. of an excessively deep tilth, and from such depths they emerge weak and etiolated.

If shortly after emergence such weakly growths are subject to a sharp frost their development is severely checked. How to treat fallow or old potato land so as to prevent it being "puffy" (*i.e.*, to avoid too deep a tilth), is an interesting question. Possibly very shallow ploughing is best, for the sole of plough gives a solid bottom, and the thin furrow slice soon dries and can be made into a fine tilth.

For some years past the advantages of "surface sowing" have been urged upon farmers by a small band of enthusiastic experimentalists. These claim that by merely pressing the seed into the surface, more rapid germination is secured, root development is favoured, and in the cereals tillering is much increased. They point out, too, that with shallow seeding drills of lighter draught can be employed. Unfortunately they are not able to adduce sound and extensive evidence, but the general principle of surface seeding undoubtedly deserves further study. There are, however, certain

definite disadvantages. Birds are able to remove surface sown seeds with great ease ; on heavy land in winter the surface sowing drills so far invented, do not work properly ; and in spring, unless suitably covered, seedlings are apt to dry out soon after germination because the rootlets are exposed.

On a hard seed-bed the coulters may not cut into the surface even when the weights are at the ends of the coulter bars. Many drills are fitted with a "presser," a simple mechanism for putting extra pressure on to the coulters.

The intervals between rows commonly adopted in sowing have been explained earlier in this chapter in discussing general sowing features of the groups of crops. It is important to understand the underlying principles. Row interval must be appropriate to the habit of growth of the crop and to the requirements of inter-cultivation. For crops carted off, *e.g.*, swedes, beet, etc., it may be desirable to adjust the interval so that the wheels of the carts "fit in." Beans, peas, corn crops, roots and seeds are useful illustrations. Beans are sown at 20–28 in. Thus they can be horse-hoed and so serve as a cleaning crop. When sown on land in high condition they branch abundantly and thus are apt to make so thick a growth that the stems become unduly long and spindly, and because of the dense shading all the pods of the bottom half of the stem die off. In these circumstances a 28–30 in. interval between rows should be adopted. For field peas (*Pisum arvense*) 20–24 in. is generally suitable. But for the earliest sowings of picking peas (*P. sativum*) on a field scale it is usual to have the rows at 16 in. or even 14 in. There are two reasons for this. Early picking peas are grown in market garden districts where potatoes, cabbages, and other "cleaning" crops are frequently taken and labour is freely employed. Thus in a pea crop which is sown in mid-March and is off by the end of June, relatively little hoeing is necessary. A second reason for close rows is that in early varieties of peas there is a far less growth of stem than in field peas. There is thus little danger of shading and of the other evils which arise from very dense crops. Corn is drilled in rows at 7–9 in. apart. This allows either hand- or horse-hoeing to be carried out, but if the land be foul and it is intended to horse-hoe thoroughly, a full 9 in interval is desirable. Experimentalists, among them Jethro Tull and Arthur Young, have from time to time advocated wider intervals. When spacing is increased, wheat, barley and oats show marked response in tillering. But the greater number of ears per plant does not, as a rule, compensate for the reduced number of plants per acre. Moreover, at wide spacing there is a high proportion of late-formed ears, some of which are unripe when the earlier ones are fully matured. In barley, such irregular maturation would, of course, seriously damage "malting quality." In root crops the problem of spacing is by no means solved as yet. Marrow stem kale if widely spaced grows into very large plants, but the stems are apt to be extremely hard.

The nutritive value of kale stems depends not only on size but on age and the proper adjustment of spacing and date of cutting to ensure maximum feeding value per acre, as distinct from bulk, has yet to be determined. Controversy still continues over spacing for sugar beet. On the Continent, rows at 14–16 in. and plants singled to 7–10 in. is sometimes the practice. This undoubtedly ensures the maximum crop possible for the soil and season on very light land. And it is economic where labour for singling is cheap. But in many English beet areas, even with small topped varieties, the foliage is too abundant for such close intervals. Apart from this, the practicability of 16–in. work in England needs consideration. Save on the most friable soils it is difficult to horse-hoe 16–in. rows without damage to the plants and to chop out to 7 in. is slow and costly. Some growers, in the face of labour difficulties, declare that with rows at less than 24 in. the extra trouble of close work is not repaid by the increased yield. Everyone must naturally adopt the interval which best suits his circumstances. But there seems little doubt that, on most beet soils in England, the full potential crop cannot be obtained if the row interval exceeds 20 in. With "seeds" crops, mixtures of grasses and clovers, the growth of individual plants is very limited. To ensure heavy yield, to choke out weeds, especially in long leys or permanent pastures, a dense and evenly distributed plant is clearly necessary. It is therefore desirable in the common practice of sowing under a corn crop, to divide the seed and sow in two directions. A convenient procedure is to sow the rye-grass and other large seeds in one direction, and the Timothy and clovers at right angles to this. Where it is desired to get a dense covering quickly and without gaps, as for instance, in sowing down land for playing fields, four sowings—in some cases as many as eight—are made. This can only be done with the heavy seed rates (100–250 lbs. per acre) employed for such fields.

The next matter for consideration is the seed-bed which, in farming language consists of a "top" or tilth, and a "bottom." For the operation of sowing, a fine tilth is desirable. It ensures free, steady movement of the drill coulters, and uniformity of sowing depth. In addition the plumules of the germinating seeds can emerge without obstruction, while the rootlets and stem bases are protected from drying out by a mulch of crumbly soil. But in making a seed-bed the farmer must consider the influence his work will have at later stages of crop life. If a really fine tilth be made for winter sowings, especially on heavy land, it will "run together," *i.e.*, become firmly set or panned under the influence of winter rains. Spring growth will thereby be adversely affected and on a panned tilth intercultivation is almost impossible in a dry spring. It is necessary therefore to adjust the fineness of an autumn tilth with great care. Heavy land farmers like a cloddy tilth for winter corn, and in some districts the wind-breaking power of clods is regarded as a great asset. Wetness often makes it impossible to

get a fine tilth in autumn, but in sowing a fallow during a dry autumn there is considerable risk of getting the top too fine.

The bottom of a seed-bed must be firm without being unduly compacted. The principles may be illustrated by beet, wheat, onions and grass. Many years of shallow ploughing have produced in some fields a hard plough pan. This reduces percolation of rain water and offers strong resistance to root penetration. If sugar beet is to be grown on such a field, deep ploughing and subsoiling are desirable. But these must be followed by other operations (*i.e.*, harrowing and rolling) so as to avoid a "puffy" or "hollow" bottom. To ensure good germination of beet or other spring-sown seed, the bottom must be sufficiently firm to allow of steady rise of sub-soil water. The headlands of a piece of wheat are often seen to carry an outstandingly good crop. The usual and probable explanation is that on the headlands there is a firm bottom. Exactly how this favours the development of the wheat plant cannot be explained. One definite advantage, however, is that the plants gain stronger root-hold on a firm bottom. This protects them from the "heaving" or forcing out induced by the expansion on freezing of soil water; and in July and August it helps to prevent lodging. That corn so commonly lodges in the Fens is due largely to the abundance of growth on these rich soils; but it is also in part attributable to the loose peaty bottom.

It is well known that, save on heavy soils in wet weather, the seed-bed "cannot be too hard" for onions and for grass. A very firm bottom and shallow fine top is ideal. Development of these crops is favoured by such a combination, and, probably most important of all, an adequate rise of water is ensured to the roots.

How to prepare a suitable top and bottom belongs to the Chapters on Cultivation. It must suffice here to urge the student to study by close observation the precise effects produced upon the soil by the plough, the cultivator, the roll, and the various harrows. He will perceive that the harrow, like the rake in the garden, not only breaks up the soil but does much to consolidate its top layers.

The general adoption of "transplanting" in sowing farm crops has recently been urged, and a "transplanting machine" is now on the market. This may be used not only for cabbage, lettuce, kale, and the other crops which are frequently transplanted by hand, but also for the cereals. Perfectly regular spacing and very favourable conditions for plant development are among the suggested advantages. Time must show what merits attach to transplanting with farm crops, but certain difficulties are patent. Seed-bed sowing followed by transplanting of cereal crops involves two operations in place of a single drilling. With present models a great amount of manual labour is necessary for lifting the plants and loading them into the transplanting machine. To gauge the sowing time which will ensure plants of appropriate size when the land and time make transplanting possible, is not by any means easy with cereals. In autumn wet land may interfere with the working of the

machine ; in spring transplanted cereals may suffer from drought ; and at the relatively wide interval of transplanting, crops would not so readily choke the weeds in early life as they do when drilled in the customary manner.

It is with seed mixtures (combinations of grasses and clovers) that problems of seed rate and sowing become most interesting and most difficult. These matters cannot be closely discussed here. But the student should try to apply the general considerations of this chapter to the seeding data given in the Chapter on Grasses. For this Table II. will be helpful. About 30 lb. per acre of "seeds mixture" is commonly sown per acre but it may be composed of very different ingredients. Comparisons of population density may be made for three such sowings as :—

	(Mixture in lbs. per acre). A.	B.	C.
Perennial Rye Grass	30	18	16
Cocksfoot	—	6	—
Timothy	—	1	1
Rough Stalk Meadow Grass	—	2	3
Chewing's Fescue	—	—	6
Broad-leaved Red Clover	—	—	2
Late-flowering Red Clover	—	4	3
Wild White Clover	2	1	1
	32	32	32

Some of the fundamental considerations connected with seed rate and sowing have been subject to enquiry in recent studies of field crops. These began with a determination of the distribution of the plants along the drill rows. Great irregularity was found in all fields and all crops. Thus, taking a drill row of wheat plants, foot length by foot length, there might be found on the first foot, 6 plants, on the next 13, then 0, 17, 8, 24, 3 . . . Normally the number of plants per foot length of row fluctuated between 0 and 40 in cereal crops. On a foot length with 4 plants, tillering was more abundant than on one carrying 20 plants. But at harvest, while the average ear size and average number of ears per plant were greater, the yield of grain was less. It was shown that in typical field crops some 50–60 per cent. of the foot-lengths of row were under-populated, and therefore yielding below the full rate appropriate to the soil and season. For full potential yield about 18 plants on every foot length of row appeared to be desirable in cereal crops. Similar studies were made on field crops of sugar beet. There was considerable sacrifice of yield as a result of gaps and irregularities in the mature crop, and these defects were traced to irregularities in the seedling (un-singled) plant. Among the circumstances responsible for this universal irregularity of plant distribution were damage by pests, bad seed, rough tilth, and faulty drill action. In all cases uneven deposition of seed by the drill was the most important. The experiments were of some complexity, but a popular review may be found in the Royal Agricultural Society of England publication, "Agricultural Research in 1928,"

pp. 7–13. By making counts of seeds sown, plants surviving, tillering, and ear formation, on foot lengths of row at four or five periods during crop life, the student may readily gain an understanding of the importance of a full and even plant. If he supplement counting by close observation of tilths and sowings, he will meet interesting illustrations of the general principles with which this chapter has dealt.

CHAPTER XI.

WEEDS.

EVERY farmer knows what weeds are and yet it is a troublesome matter to frame a definition of them. " Plants growing in the wrong place " or " plants that interfere with crops to their detriment " are well known among the many ingenious attempts. The happiest is undoubtedly the epigram attributed to a bishop—" Agriculture is a controversy with weeds." Only when a definition is attempted do the subtlety and complexity of the weed question become apparent. Most weeds are objectionable because, by competition, they interfere with the growth of crops. But one crop may be a weed in another as with shed corn or potatoes left in the ground. Again, in grassland, certain forms may find their way in, *e.g.*, Agrostis which, while of some feeding value, are of less value than the sown grasses and clovers which they tend to suppress.

There is a vast weed-lore, passed on down generations of farmers, and scientific knowledge of weeds is also very wide. The student must not expect to find in this brief chapter even a summary of all that is known about weeds. What is written here seeks simply to introduce to him the essential principles and the major facts in the hope that he may be encouraged to think out his weed problems with originality and on sound lines. To guide those who seek more detailed knowledge there are reviewed, at the end of the chapter, a few books of outstanding value.

Damage by weeds is manifold. The commonest is stultification of crop plants by competition. This takes the form not only of withdrawal of plant foods from the soil but of crowding and shading of the aerial parts of the crop plants. A few weeds are actually parasitic on crops. Some are total parasites having no chlorophyll and thus, forming no carbohydrates themselves, depending solely upon their hosts. Examples are : " dodder " (Cuscuta) found on clovers and other legumes (*C. trifolii*) and on flax (*C. epilinum*) ; and " broomrape " (*Orobanche minor*) which becomes attached to the roots of red clover, lucerne, and sainfoin. Not infrequently this last-named parasite has ruined a whole field of clover. There are also partial parasites which, though having chlorophyll and making part of their own food, depend in the main upon their hosts. In wheat fields the red " bartsia " (*Bartsia odontites*) is often plentiful

and though never serious is a partial parasite. Another example of this class, "greater yellow-rattle" (*Rhinanthus major*) sometimes seriously affects wheat and other cereal crops.

Some weeds are important as alternative hosts for fungi or insect pests of crops. Charlock harbours "finger and toe" (*Plasmodiophora brassicae*), a serious disease of turnips and other cruciferous crops; the "white rust" (*Cystopus candidus*) which attacks cabbages commonly occurs on shepherd's purse; thistles harbour the mangold fly (*Pegomyia beta*); and the notorious bean aphis or black fly (*Aphis rumicis*) often lays its eggs on fat hen, docks, thistles, and poppies.

Farm produce may be much reduced in value by weeds. Milk tainted by the wild onions known as "garlic" (*Allium vineale*) and "ramsons" (*A. ursinum*) has often been reported. Wheat may easily become unsaleable because of the presence of "onion" bulbils (*Allium vineale*) or of seeds of the corn cockle (*Agrostemma Githago*, or *Lychnis Githago*). Onions give flour a nasty smell while the black seeds of cockle may be mistaken for mouse-droppings and, in any case, when ground, discolour the flour.

Certain plants, among them a number of weeds, are poisonous to stock. Some of the deaths attributed to plant poisoning are undoubtedly due to altogether different causes. The following, however, have proved to be dangerous weeds: —

Bell-bine (*Convolvulus arvensis*).
Buttercups (species of *Ranunculus*).
Corn Cockle (*Lychnis Githago*).
Fool's Parsley (*Aethusa cynapium*).
Hemlock (*Conium maculatum*).
Horsetails (mainly *Equisetum arvense*).
Meadow Saffron (*Colchicum autumnale*)

Information about other poisonous weeds may be found in reference (6) at the end of the chapter.

The normal operations of the field may be much interfered with if weeds abound. Roots cannot be hoed and singled at the proper time if the line of the rows is obscured by weed seedlings. Where bell-bine (*Convolvulus arvenis*) or other climbing weeds are common in corn the work of the binder may be impeded and carting is sometimes delayed because the sheaves require unusually long drying.

But in practice all these forms of damage and loss are of minor importance. The average farmer keeps his land more or less clean, and it is the great cost of the unending "controversy with weeds" that represents their true significance. Thus it behoves every farmer to make careful study of the weed problem. The practices proved sound by experience and the increasing resources of science must be well understood; but the essential basis is a knowledge of the habits and characteristics of weeds. For identification and morphological description of individual weeds the student must use a suitable text book (*e.g.*, reference (1) at the end of the chapter).

Here only the general features of weeds at large can be discussed.

Weeds like all other plants may be classed as annual, biennial or perennial. Annuals complete their life cycle in a single year. Propagation is solely by seed which, in most cases, is produced in great quantities. Most are shallow rooted and therefore easy to kill. Their characteristics suggest the general lines of control. Seed which is in the ground must be given good opportunities to germinate and then destroyed in the seedling stage. Some seedlings, especially those which germinate late, will escape and grow up. Steps must therefore be taken to prevent them from seeding. The old maxim "One year's seeding seven years weeding" is, and deserves to be, repeated whenever annual weeds are discussed. Some forms reach the seed-bearing stage very swiftly and a few, called "ephemerals," *e.g.*, chickweed and groundsel, may produce two crops in a season. These two, with the poppy, the speedwells, scarlet pimpernel, charlock, wild radish, cleavers, fumitory, fat hen, annual meadow grass, slender foxtail grass (or black grass), and cleavers (or goose grass) are the commonest examples of annual weeds.

The annual weeds common in a district appear in more or less regular succession. Thus quite early in the year annual meadow grass may make its appearance; towards the end of winter field speedwell, shepherd's purse, and chickweed germinate; then come knot-grass, later fumitory, and after these the milk weeds or spurges as spring advances. To meet these waves of invasion a succession of cleaning operations is needed and only by observation of characteristic times of appearance can such cleanings be made effective and yet economical of labour.

Prolificacy in seed production and great viability of seed are impressive features of some annual weeds. Several estimates have been made of seed production by common weeds and the following illustrations are drawn from the work of Dorph-Petersen :—

	No. of seeds per plant.
Wild carrot	4,000 to 110,000.
Ox-eye daisy	1,300 to 26,000.
Scentless mayweed	310,000 (average).
Narrow-leaved plaintain	2,500 to 15,000.
Sow thistle...	3,000 (average).

The seeds of most crops and weeds have their germinating capacity reduced to about 50 per cent. after four years' storage and after eight years or so no viable seeds remain. But experiment has shown that in some plants vitality remains over much longer periods. Of 107 species tested by burying the seeds in soil at various depths, no less than 51 showed some viable seeds at the end of 21 years. Fat hen showed 30–40 per cent. of living seeds after 16 years burial at depths ranging from 8 to 42 in. and docks, black night-shade, and broad-leaved plantain were prominent examples of great seed longevity. Charlock may grow in abundance where 20-year-old grass is ploughed up or silt from a neglected open drain

is thrown out ; and it is well known that deep ploughing is often followed by abundant growth of charlock from seeds which have long been dormant in the sub-soil. As it is so often alleged that plants have been grown from wheat and lentil seeds immured for thousands of years in tombs, it may be well to point out that this intriguing story is no more than a story.

Biennial weeds complete their life cycle in two years. In the first reserves of food are stored, seed being produced in the second. This habit is ill-adapted to survival on cultivated land and there are few biennial weeds. Wild carrot may, however, be fairly common in sainfoin and the spear thistle, marsh thistle and hemlock (in the hedges) are not unfamiliar biennials in grass.

In perennials, although seed is formed, survival and increase are also ensured by vegetative means. Food is stored in fleshy rhizomes or underground stems (*e.g.*, couch grass) or in roots (*e.g.*, dock) from which buds arise in the following spring. These develop into new units with roots and leaves of their own and in their turn set up food reserves and so spread the plant over an ever-increasing area. Storage organs and their buds are able to withstand drying and exposure to frost for considerable periods. Moreover, cultivations which break them up into pieces without killing them, simply promote the spread of the plant. These facts must be kept in mind in devising means for eradicating perennial weeds.

Growth habit of weeds deserves attention. Forms with a single root and long trailing branches may choke considerable numbers of young plants, especially in the root crop. Knot grass and some of the wild geraniums are common examples. Dandelions, the greater plaintain and daisies, have a markedly flattened or rosette habit. Every plant thus dominates a considerable patch of ground and in some pastures the loss so occasioned is serious. A particularly pernicious habit is the formation of stolons or creeping stems with the development of roots and shoots at every node. Some species of *Agrostis* (bent grass or water grass), assisted by this habit, are able to occupy the spaces among the desirable plants in grass fields and bit by bit to suppress the more valuable grasses and clovers. The rooting is shallow so that repeated harrowing is a helpful check.

Strength of stem and of root is an important feature and cleavers illustrate this. Sometimes this weed is allowed to grow in spring corn until the stems are several inches long. Eradication is then attempted by harrowing. The fragile stems break but the roots are not seriously disturbed. In effect, therefore, the cleavers are merely pruned and soon grow again. If the corn grows with sufficient rapidity to choke the cleavers while they are commencing re-growth, harrowing is sound practice. But a horse hoeing (shaft or wheel hoe) or earlier harrowing is much the better practice. Shepherd's purse, knot grass, and hog's cress are examples of weeds with very strong roots. If allowed to attain a fair size they are difficult to cut out even with a well sharpened hand hoe.

Some of the most obstinate weeds are those that penetrate to a great depth. Bell bine, wild onion, dandelions, and dock are notorious examples.

The ecology or adaptation of weeds is an interesting study. Associated with different soil types are commonly found certain groups of weeds which therefore serve as soil indicators. Common examples are :—

On badly drained soils : meadow sweet, cowslip, silver weed, coltsfoot, rushes, some sedges, some mosses, and horsetails.

On heavy land : creeping buttercup, beggar's lice, coltsfoot, slender foxtail.

On highly-farmed land, well drained and not very heavy : creeping thistle, stinging nettles, fat hen, chickweed, cleavers, and sow thistle.

On the lighter soils in poor heart : ox-eye daisy, sterile brome grass, rest harrow, Yorkshire fog, bent grass (water grass) in grass fields, and, especially if lime be deficient, spurrey and sheep's sorrel.

On calcareous soils : bladder companion, lady's mantle, white campion, chicory, burnet.

On soils deficient in lime : spurrey, sheep's sorrel, cornflower, corn marigold, bracken.

Only a few common examples are given above. Which weeds are in association with a soil type depends markedly upon climatic factors and therefore upon locality. In one set of circumstances bracken may be the familiar index of lime shortage ; in another spurrey and sheep's sorrel.

Weeds may to some extent be indicators of fertility. Thus some land is so poor in inherent soil properties and so low in fertility that only poor land weeds survive there (see list above) and even these are stunted. Really well grown specimens of fat hen, nettles, chickweed, and even couch grass, are by some farmers regarded as signs of high fertility.

Careful attention should be given to the ways in which weeds are introduced into an area. Local introduction, that is from other near-by areas, is usually simple. The seeds of many plants, *e.g.*, poppy and chickweed, are very light and therefore readily transported by wind. Others, *e.g.*, thistles, dandelions, etc., have a parachute-like "pappus" of hairs. The threshing drum and other seed machinery may carry weeds and certain fungoid diseases (*e.g.*, bunt) from farm to farm. Birds, mice, and other animals may also be agents in distribution. Farm-yard manure and seed are probably the most important of the controllable agencies of weed dissemination. Dirt and other screenings from the threshing drum are sometimes thrown on to the manure heap to which weeds may also find access from hay fed to stock and in which weeds are abundant. In India impurity in cotton, *i.e.*, admixture of varieties, has been traced to the feeding of cotton seed to the plough bullocks. Crushing or boiling the seed before feeding has proved an effective prevention. Many seeds will pass through an animal with germination capacity

unaffected. Hence manure known to contain weed seeds should not be used until it has lain for some months in the mixen.

Seeds of annual weeds are unlikely to be harmful on well-established grass, so that if fresh dung, known to contain such weed seeds, has to be applied, it should be used for the grass fields.

Seed containing weeds is sometimes sown especially when farmers use their own seed. The danger from this source may be appreciated from the fact that 1 per cent. (by weight) of dock seed in a mixture of grasses and clovers results in the sowing of an average of at least ten dock seeds per square yard. Devil's cress or Thanet weed (*Lepidium draba*) is one of the most notorious examples of the dangers from seed impurities. In parts of Essex and Kent it has almost put some land out of cultivation, while in Hertfordshire and Cambridgeshire the rapidity of its spread is alarming. Not only does it seed freely, but its deep, fleshy roots make eradication extremely difficult and costly. By means unknown, it has reached the United States, Australia, and New Zealand and in parts of these countries is counted one of the worst weeds of arable land. How it reached England is doubtful. One authority states that it was introduced in the straw-filled beds of soldiers returning from a European campaign in 1809. But there is evidence that it has come repeatedly in lucerne, sainfoin, and clover seeds imported from the Continent.

Certain legal enactments deal with the introduction and spread of weeds. Seeds Acts passed in 1920 and 1925 with Seeds Regulations issued under the authority of these Acts, compel anyone selling seed or offering it for sale to declare in writing at or before sale or delivery certain particulars as to purity, germination, and presence of injurious weeds. A farmer selling seed to a neighbour must comply with these Regulations, and all who handle seeds in any way should be familiar with them. They are necessarily somewhat elaborate and cannot be fully explained here. In practice they are a most valuable safeguard for the farmer and need cause him no trouble whatsoever. The Official Seed Testing Station (part of the National Institute of Agricultural Botany, Huntingdon Road, Cambridge) will deal with any inquiry concerning the purity and germination capacity of seeds. Tests are made for farmers or seedsmen on payment of a nominal fee and the organisation is such as to ensure the issue of results of tests and of special advice without any delay.

Legal action may be taken under the Agricultural Committees (Injurious Weeds) Order, 1921, to compel an occupier to clean land which, by reason of heavy weed infestation, constitutes a danger to neighbouring land. The weeds to which the Order refers are ragwort, spear thistle, creeping thistle, curled dock, and broad-leaved dock. Complaints under the Order must be made to the County Agricultural Committee.

The particular seriousness of weed impurities in grass and clover mixtures should be noticed. It is in these seeds that impurities

most commonly occur and as the crops—short leys or permanent grass—occupy the land for a long time, the introduction of even the smallest proportion of weeds is a grave danger.

In every arable district there are some weeds which thrive particularly in certain crops. The influences of different types of weed upon crops have been discussed and it is equally necessary to be acquainted with the influence exerted upon weeds by various crops and systems of farming. For it is a cardinal principle of weed control to exploit as fully as possible the smothering effect and other influences and opportunities associated with the various crops. To the general body of farming experience upon this point may be added Dr. W. E. Brenchley's valuable data upon the weeds notably absent from or present in crops (for full details see Ref. (4) at the end of the chapter).

Root crops have, inherently, no special powers of suppression, but they lend themselves to weed eradication. Sown in spring they leave the land free in March and April when sun and wind normally favour cleaning. Moreover, being sown in wide rows and singled, they give full play to hand and horse hoe. While always referred to as the "cleaning" crop of the rotation they do not always function as such in practice. The horse hoe will not clean between the plants in the row as some fields bear witness. Further, on heavy clays in the Eastern Counties, where spring droughts are common, the root fields are often so hard in June and July that the horse hoe "jumps" badly and destroys more crop plants than weeds. For this reason roots are now often omitted from the rotation on the heaviest farms and cleaning is effected (sometimes nominally only) by a "smother crop" of seeds (a typical rotation would be beans, wheat, oats, seeds and when the land is becoming foul, a bare fallow after the seeds). The present tendency to displace roots (where sugar beet is not profitable) because of the labour they involve is likely to prove a serious factor in weed control.

The spring corn shift affords good opportunities for assailing weeds. Many seeds are buried too deep for immediate germination by the ploughings preparatory to sowing spring corn but, especially if the weather be favourable, the corn is soon sufficiently luxurious to smother most of the weed seedlings. The fresh, fine tilth, too, favours horse hoeing (shaft or wheel hoe).

Seeds, provided the plant is full, have splendid smothering power. Some of the campions and geraniums can survive shading and therefore appear in the seeds shift, but the suppression of annual meadow grass, fat hen, dead nettles, knot grass, spurrey, chickweed, and speedwell is usually well marked. A special case of suppression by a "seeds" crop is presented in the practice of sowing trefoil or black medick (*Medicago lupulina*) with sainfoin. This helps to make a good cut in the first year and also smothers the weeds. In later years the sainfoin is able to hold its own, whereas, if sown alone, weeds often inhibit it in the first year and gain permanent foothold. Unfortunately seeds will not smother wild

parsnip, wild carrot, dock, and other similar weeds, and this is the undoing of those who, on the wettest clay farms of East Anglia, are obliged to trust to the seeds shift as their cleaning crop.

Winter corn, in general, favours the weeds rather than the farmer. Before full spring growth gives definite smothering power, some weeds have germinated and gained firm hold. Perhaps the best examples are beggar's lice (or field buttercup), black grass (*Alopecurus agrestis*), and wild oats. These germinate in early winter, easily survive the competition of the corn, and shed their seed before the crop is cut. Where, as described above, for very heavy clay, the rotation includes neither root nor spring corn shift, these two weeds become a serious menace. A bare fallow temporarily checks them, but dormant seeds are so numerous that there is soon again a full infestation. Regular spring corn in the rotation is the best safeguard. Horse hoeing is more difficult in winter than in spring corn, for the land (if heavy) is panned and rather hard by the time that it is sufficiently dry to hoe. The disadvantages of winter corn may be lessened by thorough stubble cleaning.

Peas—whether the field or table type—are the "dirtiest" crop of the farm. When they are 6–8 inches high they begin to "sprawl" and cultivation is therefore impossible. But a considerable time elapses between the latest possible hoeing and the development of such an amount of stem and leaf as will give smothering power. It is in this interval that weeds find their chance. Seldom is the land left in anything but a fairly foul condition after a pea crop. With beans difficulties are similar but far less severe, for cultivation can be longer continued. Further, most beans are winter sown and therefore develop their smothering power fairly soon after the last horse hoeing. This power, however, is not very marked unless there is a full plant and abundant growth.

In weed control there are certain general principles which should govern the employment of the various specific methods derived from farming experience and from science. If cost were no consideration the land could be kept clean simply by constant onslaught upon the weeds. But in all systems of farming weed destruction is costly and costs can be kept within reasonable bounds only by intelligent attack. In so far as agriculture is a "controversy with weeds" it must be conducted in a spirit of well-informed aggression and the general principles are closely parallel to those on which modern warfare is based.

The first principle is to get full information about the characteristics of the enemy and to watch its movements closely. Next, every favourable opportunity for attack which presents itself must be seized; and if necessary, opportunities must be made. To a considerable extent the design of any good rotation represents the making of opportunities for attack upon weeds. Thus in the ordinary four-course, the root break allows direct attack during a considerable part of the year—by the plough and cultivator before

drilling and by the horse hoe when the crop is growing. Pre-crop cleaning is possible before the barley is sown, while the seeds shift "swamps" out many weed forms by its dense growth. Again, in the stubble-field, a valuable opportunity for attack may be made. By once or twice broadsharing the stubbles and so breaking up the top "crust" of the soil, great numbers of weed seeds are encouraged to germinate and all these may easily be killed by the normal ploughing.

Timing of the attack requires careful consideration and prompt decision. On a day in late April or May when there is bright sun and a drying wind, hoeing is extremely effective. But during a wet spell the same implement merely "moves" the weeds without properly exposing the root, so that, in a short space, growth is resumed. For most weed treatments there is a stage at which the enemy is particularly vulnerable. In the seedling stage weeds are killed by a mere touch of the hoe. As they grow old their root hold gets firmer and deeper and eradication is thus far more difficult. Again, in the use of sprays full success requires: that the weeds should be small enough to succumb when sprayed with a moderately strong solution; that they should have sufficient foliage to be "caught" by the spray; and that the crop plant in which they are growing (*e.g.*, barley with charlock in it) should not be so far advanced as to suffer significantly from the spray. In practice there is no time at which all these conditions are fulfilled and to choose the most favourable time calls for sound judgment.

The attack must be driven right home and the enemy completely destroyed. Thus where beans have to be used as the main cleaning crop it is not very effective to horse hoe between the rows, leaving a dense growth of rubbish in the rows. Many attacks fail because they are launched on too wide a front. If a really foul farm has to be taken over with no more than normal labour strength it is wise to concentrate on a few fields every year rather than to make a half-hearted attack upon the whole.

The feature of weeds which dictates the most important general principles is their method of increase. For annuals (and the few biennial weeds) this is by seed, and unless seeding is prevented there can be no victory. Perennials, increasing by vegetative means, are more difficult. Upon them the repeated skirmishing attack with the hoe has little effect. They must be attacked in strength by deep ploughing or fallowing. When they first begin to invade a field hand lifting is well worth while.

All these principles must be borne in mind in applying the specific methods which are now to be reviewed.

Insistence on weed-free seed, care with dung, a good rotation, and certain other weed control measures which have already come under notice, need no further mention. Grass-land weeds are dealt with in a later passage. The remaining methods come under the headings of handwork, cultivations, fallowing, and chemical treatment. In some countries, *e.g.*, Australia and Great Britain, efforts

are being made to devise biological control of weeds. This implies the introduction of some insect, fungus, or other organism which is particularly destructive to the weed. So far only the experimental stage has been reached.

Hand methods are very costiy, but are sometimes justifiable. Invasion by a new and dangerous weed should be met, at the outset, by hand eradication (*cf.* the case of devil's cress already cited). The sides of a cart road often harbour couch which bit by bit is carried by ploughing, harrowing, etc., into mid-field. Some farmers find it worth while to fork the sides clean every 2–3 years. Repeated cutting and spudding will ultimately destroy those perennials which have tall stems, *e.g.*, thistles. By allowing them to grow until on the point of flowering, then cutting, and after re-growth cutting again, they may be exhausted.

Deep ploughing helps to extirpate thistles and other perennials and by deeply burying weed seeds causes a proportion of them to rot. The horse hoe, of which two main types are employed (the wheel-less and the shaft hoe) is the standard implement for use against weeds. As already explained its efficiency very largely turns on the condition of the soil and the nature of the weather at the time of hoeing. The special features of stubble cleaning, using the broadshare cultivator, should be carefully borne in mind: they have already been described. In hoeing root crops the shaft hoes with a disc at each side of every blade make it possible to hoe close up to the plants even in the very early stages of growth.

Fallowing is a difficult art often practised with vast skill by heavy-land farmers for whom, in spite of its immediate economic disadvantages, it is from time to time a necessity. In essence it consists of a ploughing in spring to throw up the land into well-formed furrow slices which are allowed to dry out completely into "blocks" or huge clods. Couch and other perennials are thereby "baked out" and when this has been effected the blocks are broken up by the cultivator and harrow to expose and germinate the weed seeds dormant in them. Only a stiff clay will block up well and the nicest judgment is required to kill all the weeds and yet leave a suitable fineness of tilth and firmness of bottom for the next (autumn sown) crop. Mistaken zeal often results in too fine a tilth which pans badly in the autumn rains and ruins the seed bed. On lighter land couch is dealt with by ploughing and, when the furrow is drying, dragging out by the harrow. Soil conditions must be exactly right for this and great care is necessary in choosing first a harrow to pull out the couch and then another (usually a chain harrow) to collect it for burning.

Chemical treatments consist in the use of sprays or powders. Copper sulphate is often sprayed on to charlock in corn; certain other weeds also succumb to it; and sulphate of iron is in many cases successful. Wet sprays must be applied when the weeds are dry, *i.e.*, not in or immediately after rain. Powders (dry sprays)

should correspondingly be used in the early morning when the leaves are dew-covered. Finely ground kainit is the most useful powder treatment and it has produced excellent results in corn crops foul with charlock. Every form of spraying results in a certain amount of injury to the crop. Cereals suffer least, especially when young, because of the narrowness and set of their leaves. Where they are undersown with seeds, however, caution is necessary. The form that caution should take cannot be specified. All the circumstances, especially the state of the crop itself, must be considered and solutions of two-thirds the usual strength are probably advisable. Before employing sprays study of the details should be made and reference (1) (Long, H.C.), p. 26 and p. 48 will prove a useful guide. Reference (7) may also be consulted.

On grass-land the weed problem is peculiarly interesting and of great practical importance. The direct action regularly taken against weeds on arable land is here impossible; and, since, if hungry enough, stock will eat almost any weed, the farmer is apt to fall into unthinking toleration of grass-land weeds. If the watchfulness, determination, and ingenuity (sometimes) brought to bear on the weeds of the tennis court and cricket field found its way into our meadows and pastures, there would soon be a vast improvement in the national agricultural resources. Hand spudding and other costly treatments are usually impossible on the field scale, but there are certain lines of action which, persistently followed, are bound to bring success. The first essential is to form a clear idea of the meaning of weeds in grass. Some plants like horsetails (*Equisetum*) are poisonous; others like wild onion taint the milk; many—including commonly thistles, the larger plantain, ox-eye daisy, wild carrot, buttercup, swine's cress and hogweed—are of no feeding value at all.

On wet, heavy, neglected grazings in East Anglia the whitethorn is a characteristic and most dangerous invader. Apart from the space occupied, it pulls the fleece of sheep, and if left alone becomes an impenetrable thicket. All these weeds are obviously bad and should be attacked by spudding and repeated brushing. It is particularly necessary to deal with them in newly-sown grass before they gain a firm hold.

Next in the scale is a number of plants which really hungry beasts will graze, but which have very little food value. The brome and false brome grasses, rushes and sedges are well known examples.

Merging into this group are certain plants which, of some food value and in special circumstances of considerable value because the better grazing species will not thrive, may yet rank as weeds because, by excess, they inhibit more valuable forms. Among them are yarrow, burnet, sorrel, and the three grasses: couch, Yorkshire fog, and water grass or bent (*Agrostis*). The last named is the best example. Woodman has shown that its young growth is highly

nutritious. When older it is coarse (fibrous) and unpalatable. Moreover its abundant creeping stems (stolons), rooting at every node, soon suppress most other grasses and are the worst foe of wild white clover. It is often stated that this grass is a sign of wetness, but this is a half truth. Essentially, it is a sign of soil poverty in the broad sense. Grass-land on heavy, undrained clay is always invaded by water grass and, indeed, in time becomes almost pure water grass. But equally severe invasion may be seen on thin sandy soil overlying chalk where the natural drainage is extremely sharp. The vulnerable feature of water grass is its stoloniferous habit and shallow roots. By repeated harrowing it may be removed in great quantity. And—a point of great importance—if other creeping plants, especially wild white clover, can be encouraged, water grass may be defeated by the tactics which are so characteristically its own.

Among the mosses—cryptogamic or non-flowering plants—are certain which frequently invade grass fields. Though so commonly associated with abnormal wetness they have a considerable range. Thus, after the very dry summer of 1929 when, in East Anglia, all but the best grass fields were full of small bare patches, moss completely filled in the spaces. Harrowing and encouragement of grasses and wild white clovers by manuring, are the most effectual treatments for moss.

There are six cardinal principles for weed control in grass-land: (1) when sowing down grass ensure a dense plant, use seed free from weed impurities, and make sure the land is free from perennial weeds; (2) persistently spud or cut thistles, thorns, and other big weeds; (3) harrow out water grass (bents); (4) make sure that fertility is maintained; (5) drain when necessary; (6) graze as hard as possible. Now these are six familiar recommendations, but attention must be called to certain aspects of them which are commonly neglected. Everyone harrows his grass in spring—or is apt to be chaffed by his neighbours for neglect. It is simple and inexpensive and leaves on the face of the fields those attractive up and down strips which we all admire through the windows of the train. Theoretically, too, it "aerates the surface of the soil." But in harrowing—as in all cultivations—it is necessary to observe closely the actual effect produced. A single harrowing may do little to disturb either water grass or moss and it is to be doubted whether, on much of our grass-land, the customary process is of any real value. Some three to five harrowings, using a suitable type of harrow, may, however, be of great advantage where water grass is abundant.

Maintenance of fertility is an important anti-weed measure. Grass, like arable crops, must be given nitrogen, phosphates, and potash. Precise requirements depend upon locality and other circumstances. But over wide areas there is a shortage of available nitrogen, and as a result water grass and other weeds make headway against the plants desired for feed. It deserves to be noticed that

applications of sulphate of ammonia (especially with sulphate of iron) *have a considerable effect in* weed suppression by direct action on broad-leaved weeds as well as by promoting development of more valuable plants. By judicious use of this fertilizer and a certain amount of hand lifting or poisoning (pricking with a syringe containing some weed killer); athletic grounds, race-courses and parks may be freed from even the heaviest infestations of plantain and some other broad-leaved weeds. Of equal importance is basic slag. Dressings of 8–10 cwt. per acre have again and again doubled the value of pasture by promoting the growth of wild white clover. No amount of nitrogen will assist grass-land where there is a marked lime shortage. The need for potash and lime must be carefully considered in every case. But, almost universally, a nitrogenous fertilizer and basic slag are of first importance. The encouragement they give to valuable grasses and clovers may always be relied upon to bring about a firm check upon weeds.

When all these anti-weed measures have been applied it remains to adopt that form of management which will best ensure their effectiveness ; that is, close grazing. Stock cannot be bought in and maintained simply to keep grass fields in good order ; on the other hand, without heavy stocking there can be no good grass. There is a vicious cyçle—limited stocking, prevalence of weeds (especially water grass), suppression of wild white clover, and so steady reduction in stock carrying capacity of the grass. There is a mågic cycle in which figure the counterparts of all these undesirable things. In practice, some middle course must be followed. The plea made here for close grazing is identical with what would be urged from the point of view of increasing the productiveness of grass-land : and, in fact, steps which directly increase productiveness are the steps which also suppress weeds. Remembering that water grass is in general the worst weed of grass-land, we may safelỳ say that the two best weeders are wild white clover and sheep.

A selected list of about one hundred common weeds is given with the botanical names arranged alphabetically under the Plant Families and the popular names (those employed in this chapter). In this A = annual ; B = biennial ; P = perennial. Certain features of this list are interesting. Only 26 families have to be included and among them are the Equisetaceæ (horsetails) which belong to the non-flowering or spore-forming plants. The two monocotyledonous families, Gramineæ and Liliaceæ, contain some of the most objectionable of our common weeds. Annuals, in the list, outnumber perennials by more than two to one. The families containing the greater numbers of important common weeds may perhaps be said to be : Cruciferæ (mainly annuals) ; Compositæ (annuals and perennials in about equal numbers) ; Gramineæ (annuals and perennials in about equal numbers) ; Liliaceæ (all perennials, viz., onions) ; and Ranunculaceæ. The Cruciferæ and Compositæ contain the greatest numbers of common weeds.

A LIST OF COMMON WEEDS OF ARABLE LAND.

A = annual; B = biennial; P = perennial. A complete description of all these weeds may be found in Reference (1) (Long, H C.) noted at the end of the Chapter. To trace alternative popular names of weeds the reader should consult Reference (4) (Brenchley, Dr. W. E.).

NON-FLOWERING (Spore-forming) PLANTS.

EQUISETACEÆ.

Equisetum—Horsetails ... ... P
(there are several species of which *E. arvense* is most common).

MONOCOTYLEDONES.

LILIACEÆ.

Allium oleraceum—Field Garlic ... ... P
,, *vineale*—Wild Onion, Crow Garlic ... ... P
,, *ursinum*—Ramsons ... ... P

GRAMINEÆ.

Agropyrum repens—Couch or Twitch ... ... P
Agrostis vulgaris—Bent or Water Grass ... ... P
Alopecurus agrestis—Blackgrass or Slender Foxtail ... ... A
Arrenatherum avenaceum var. bulbosum—Onion Couch... ... P
Avena fatua—Wild Oat ... ... A
Bromus arvensis—Field Brome-grass ... ... A
Bromus secalinus—Rye Brome-grass ... ... A
Poa annua—Annual Meadow Grass ... ... A

DICOTYLEDONES.

URTICACEÆ.

Urtica dioica—Big Stinging Nettle ... . P
,, *urens*—Small Stinging Nettle ... ... A

POLYGONACEÆ.

Polygonum aviculare—Knotgrass or Knotweed ... . A
,, *convolvulus*—Black Bindweed or Climbing Buckwheat ... ... A
,, *persicaria*—Redshank... ... ... A
Rumex acetosella—Sheep's Sorrel ... ... P
,, *crispus*—Curled Dock ... . P
,, *obtusifolius*—Common Dock ... ... P

CHENOPODIACEÆ.

Atriplex hastata—Spear leaf Orache ... ... A
,, *patula*—Spreading Orache ... ... A
Chenopodium album—Fat Hen or Goosefoot ... ... A

CARYOPHYLLACEÆ.

Arenaria tenuifolia—Sandwort ... ... A
Cerastium vulgatum—Mouse-ear Chickweed ... ... P
Lychnis Githago (= *Agrostemma Githago*)—Corn cockle ... ... A

Lychnis alba—White Campion ... ... B

Silene vulgaris—Bladder Campion ... ... P

Spergula arvensis—Spurrey ... ... A

Stellaria media—Chickweed ... ... A

Scleranthus annuus—Knawel ... ... A

RANUNCULACEÆ.

Ranunculus arvensis—Field or Corn Buttercup or Beggar's Lice A

,, *repens*—Creeping buttercup ... ... P

,, *bulbosus*—Bulbous buttercup .. .. P

PAPAVERACEÆ.

Papaver rhœas—Poppy ... ... A

,, *dubium*—Poppy ... ... A

Fumaria officinalis—Fumitory ... ... A

CRUCIFERÆ.

Brassica sinapis (= *Sinapis arvensis*)—Charlock ... ... A

Capsella bursa pastoris—Shepherd's Purse ... ... A

Lepidium campestre—Field Pepperwort ... ... A

Lepidium draba—Devil's Cress or Thanet Weed ... ... P

Raphanus raphanistrum—Wild Radish, Runch or Jointed Charlock ... ... A

Senebiera coronopus—Swine's Cress or Wart Cress ... ... A

Sisymbrium officinale—Hedge Mustard ... ... A

Sisymbrium alliaria—Jack by the Hedge ... ... A

Thlaspi arvense—Penny Cress ... ... A

ROSACEÆ.

Alchemilla arvensis—Lady's Mantle ... ... A

Potentilla anserina—Silver Weed ... ... P

,, *reptans*—Creeping Cinquefoil ... ... P

GERANIACEÆ.

Geranium dissectum—Cut-leaved Cranesbill . . A

,, *molle*—Dovesfoot Cranesbill ... . A

,, *Robertianum*—Herb Robert .. .. . . A

EUPHORBIACEÆ

Euphorbia exigua—Dwarf Spurge... ... . . . A

,, *helioscopia*—Sun Spurge ... .. . A

,, *lathyris*—Caper Spurge ... . B

,, *peplus*—Petty Spurge ... . . A

VIOLACEÆ.

Viola tricolor—Corn Pansy or Heartsease . . . A

UMBELLIFERÆ

Ægopodium podagraria—Goutweed . P

Æthusa cynapium—Fool's Parsley . A

Daucus carota—Wild Carrot ... . . . A

Scandix pecten-veneris—Shepherd's needle or Venus Comb . A

Torilis nodosa—Hedge parsley .. .. . A

	PRIMULACEÆ.	
Anagallis arvensis—Scarlet Pimpernel	...	A
	CONVOLVULACEÆ.	
Convolvulus arvensis—Field Bindweed	...	P
,, *sepium*—Great Bindweed, Bearbine	...	P
Cuscuta epilinum—Flax Dodder	...	A
,, *europæa*—Dodder of Vetches, Wild Carrot, etc.	...	A
,, *gronovii*—Dodder of Lucerne, etc.	...	A
,, *trifolii*—Clover Dodder	...	A
	BORAGINEÆ.	
Anchusa arvensis—Bugloss	...	A
Echium vulgare—Viper's Bugloss	...	A
Lithospermum arvense—Corn Gromwell	...	A
Myosotis arvensis—Field Forget-me-not or Scorpion grass	...	A
,, *versicolor*—Forget-me-not	...	A
	LABIATEÆ.	
Galeopsis tetrahit—Hemp Nettle	...	A
Lamium album—White Dead Nettle	...	P
,, *amplexicaule*—Henbit or Henbit Dead Nettle	...	A
,, *purpureum*—Red Dead Nettle	...	P
Mentha arvensis—Corn or Field Mint	...	P
Nepeta glechoma—Ground Ivy	...	P
Stachys arvensis—Corn Woundwort	...	A
	SOLANACEÆ.	
Solanum nigrum—Black or Garden Nightshade	...	A
	SCROPHULARIACEÆ.	
Linaria vulgaris—Yellow Toadflax	...	P
Melampyrum arvense—Cow-wheat	...	A
Veronica agrestis—Corn Speedwell	...	A
,, *Buxbaumii.*		
,, *hederæfolia*—Ivy-leaved Speedwell	...	A
	OROBANCHACEÆ.	
Orobanche minor—Broom rape	...	A
	PLANTAGINEÆ.	
Plantago lanceolata—Ribwort Plantain	...	P
,, *major*—Broad-leaved Plantain, Greater Plantain	...	P
	RUBIACEÆ.	
Galium aparine—Cleavers	...	A
,, *tricorne*—Corn Bedstraw	...	A
Sherardia arvensis—Field Madder	...	A
	DIPSACEÆ.	
Scabiosa arvensis—Field Scabious	...	P
	COMPOSITÆ.	
Anthemis arvensis—Corn Chamomile	...	A
,, *cotula*—Stinking Chamomile or Stinking Mayweed	..	A
Centaurea cyanus—Cornflower	...	A

Cicorium intybus—Wild Chicory ... ... P
Chrysanthemum segetum—Corn Marigold, Yellow Ox-eye ... A
Cirsium arvense—Creeping Thistle ... ... P
Gnaphalium uliginosum—Marsh Cudweed ... ... A
Lapsana communis—Nipplewort ... ... A
Matricaria chamomilla—Wild Chamomile ... ... A
,, *inodora*—Scentless Mayweed or Corn Feverfew, Horse Daisy ... ... A
Senecio vulgaris—Groundsel ... ... A
Sonchus arvensis—Perennial or Corn Sow Thistle ... ... P
,, *oleraceus*—Annual Sow Thistle ... ... A
Tanacetum vulgare—Tansy ... ... P
Tussilago farfara—Coltsfoot ... ... P

To amplify the general principles which have been outlined and for the identification of weeds and their seeds the following sources may be consulted :

(1) LONG, H. C. "Weeds of Arable Land"—Ministry of Agriculture and Fisheries. Miscellaneous Publication No. 61. 1929. Price 2s. 6d.

This discusses general principles of control, etc., but is mainly devoted to descriptions of all the commoner weeds. There are excellent diagrams and the points of agricultural interest connected with the various weeds are clearly explained. It is a standard guide to arable weeds for students and farmers.

(2) BENTHAM, G. and HOOKER, J. D. "Handbook of the British Flora." 7th edition. 1924. (1 volume of descriptions and 1 volume of illustrations.)

For the classification, full botanical description, and identification of all the wild flowering plants of Britain this is the recognised popular authority. It is not written for agricultural purposes.

(3) JOHNS, C. A. "Flowers of the Field." Revised edition. (By Boulger, G. S.) 1905.

Beginners and those with little botanical knowledge may prefer this to (2).

(4) BRENCHLEY, Dr. W. E. "Weeds of Farm Land." London. 1920. Longmans, Green & Co.

In this comprehensive treatise are discussed the botanical facts on which depend the systematic control of weeds. Methods of spread and of prevention, poisonous weeds, and the types of weed commonly associated with different crops, soils, and grasslands, are fully explained. For many weeds there is a considerable number of different local names and to these the final chapter is a useful and interesting guide.

(5) PARKINSON, S. T. and SMITH, G. "Impurities of Agricultural Seeds with a Description of Commonly Occurring Weed Seeds and a Guide to their Identification." London : Headley Brothers.

There are detailed descriptions with photographs and keys for identification together with lists of impurities associated with certain crops and countries.

(6) LONG, H. C. "Plants Poisonous to Livestock." Cambridge : at the University Press. 1924

Descriptions are given of the characteristics of all the commoner poisonous plants and of those deleterious to milk production.

(7) BOURCART, E. "Insecticides, Fungicides, and Weedkillers." Scott, Greenwood & Son, London. 1925

CHAPTER XII.

THE GRASSES: SYSTEMATICS AND BIOLOGY OF.

THE Natural Order Gramineæ is one of outstanding importance from the point of view of food production, for in addition to including the plants popularly spoken of as grasses, it includes such cereals as wheat, oats, barley, rye, maize, rice, and millet, and also a number of other valuable plants such as the sugar cane and bamboo. The group is a large one containing between five and six thousand species, distributed through all parts of the world. In this country it is represented by about one hundred species of which less than twenty can be considered of much agricultural importance. These latter are the grasses which constitute the greater part of the flora of the cultivated grasslands, namely, meadows and pastures. Species generally looked upon as weeds, though valuable under some circumstances, and the grasses of mountain pastures form a similarly sized group, whilst the remainder are plants of botanical interest only.

The characteristics of the Gramineæ are so clearly defined and so unlike those of all other groups of plants, that a grass can be recognized as such at sight with considerable certainty. But the full determination, first of its genus and then of its species, usually requires a detailed examination of the plant. The characters on which the systematic botanist chiefly relies for the classification of the grasses are provided by the flowering shoots or inflorescences. But these are insufficient for the agriculturist, who has to be able to recognize the various species either before they come into flower or when they have been heavily grazed. Such identifications are not as difficult as would appear at first sight, for the grasses differ much amongst themselves in their habit of growth, and their foliage provides a number of distinct morphological differences. Even the seeds can be identified with complete certainty if attention is paid to a few distinguishing features.

Inflorescences.—There are three types of inflorescences amongst the grasses—the panicle, the spike, and the spike-like panicle. The panicle is a branched inflorescence. A typical example is provided by a head of oats. This type is characteristic of the following genera: Agrostis (bent grasses), Avena and Arrhenatherum (oat grasses), Holcus (Yorkshire fog), Bromus (brome grasses), Festuca (fescues), Poa (meadow grasses), and Dactylis (cocksfoot).

In the spike there is a complete absence of branching and the groups of flowers or "spikelets" are seated directly on alternate notches on the central stalk, or "rachis," of the inflorescence. This form occurs in Lolium (rye grass), Cynosurus (dog's-tail), Agropyrum (couch grass), Hordeum (barley grass), and Brachypodium (tor grass).

The spike-like panicle closely resembles the spike, but if it is dissected the spikelets are found to be borne on short branches

arising from the rachis. It is found in the following genera: Phleum (Timothy grass) Alopecurus (foxtail), and Anthoxanthum (sweet vernal grass).

The structure of the flowers is singularly constant throughout the Gramineæ. It is best seen in comparatively large-flowered examples such as wheat or oats. Each flower consists of three stamens, a single carpel with a bifid feathery stigma and a pair of small, easily overlooked scales, known as "lodicules" (Fig. 30).

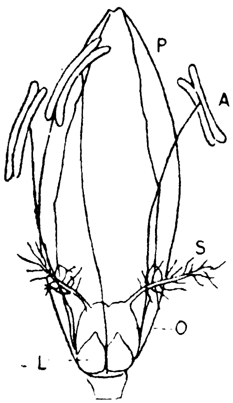


FIG. 30.
Flower of a grass with the outer palea removed. P, the inner palea; L, the two lodicules; O, the single carpel with two feathery stigmas S; and A, the three anthers.

One of the few exceptions to this type of structure is provided by sweet vernal grass, in which only two stamens are present. The flower is completely enclosed by a pair of more or less boat-shaped scales or "paleæ," one of which, the "outer palea," overlaps the edges of the other or "inner palea." In the oat several flowers are borne on a short central stalk or "rachilla," and they are completely enclosed by a pair of large chaffy scales or "glumes." In most grasses, however, the glumes are of much the same size as the outer paleæ. The whole structure, that is, glumes and flowers taken together, constitutes the spikelet. There are some genera in which the spikelet contains only one flower. This provides a useful characteristic for recognizing Phleum, Alopecurus, Agrostis, Anthoxanthum, and Hordeum (Fig. 31).

The pollination of the flowers of the grasses is dependent upon air currents. When the stamens are mature a rapid elongation of their filaments pushes the anthers clear of the slightly gaping paleæ, and they swing freely in the wind. At each puff a minute cloud of pollen is ejected through a slit at the apex of the anther. Some of the grains are thus likely to find a resting place on the fluffy surface of the stigmas, which in turn protrude from the paleæ when in a receptive condition. Cross-fertilization is further secured by the fact that the stamens and carpels on the same inflorescence may mature at different periods. Thus in the meadow foxtail the stigmas protrude from the paleæ three or four days before the stamens are ready to shed their pollen. At this stage then the flowers are to all intents and purposes female only, whilst later they become male. Self-fertilization, though probably rare in the natural state, can be effected artificially in a number of species. The seeds resulting from the application of the plant's own pollen to its stigma commonly germinate badly and give rise to plants appreciably less vigorous than the parent.

In the cereals, on the other hand, the flowers are usually self-pollinated, and their fertilization is the direct result of the anthers

dehiscing and shedding their pollen in the unopened flower. It is only when the carpel has begun its final stages of development that the paleæ open slightly, and the now useless stamens are pushed out. When this occurs the plants are often said to be in flower, and farmers become needlessly anxious about weather conditions affecting the setting of the grain.

It is on account of this self-fertilization that true breeding kinds of the cereals exist. In the grasses the crossing of slightly differing forms makes the production of similar "pure-lines" (p. 407) impossible. It also explains the fact that when seed is taken from a single plant, of perennial rye grass for instance, the resulting plants usually differ much amongst themselves.

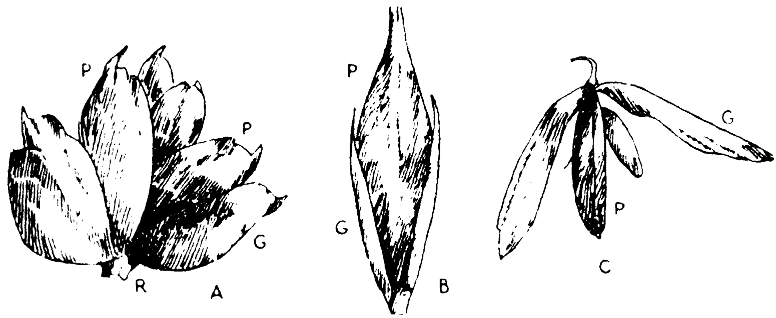


FIG. 31.—

A, spikelet of wheat showing five flowers and broad glumes.

B, single-flowered spikelet of barley with narrow glumes.

C, spikelet of oat with the large papery glumes opened out to show the two flowers.

G, glumes. P, outer palea and R, rachis.

The carpel matures to form a type of fruit known as a "caryopsis." It is particularly characteristic of the Gramineæ. The testa of the single seed fuses with the inner wall of the carpel so completely that the two structures are inseparable. Thus the so-called "seed" is, botanically speaking, a fruit. Typical examples of such seed are provided by grains of wheat or maize, but in the majority of the grasses the seeds are still more complex structures, for the caryopsis is generally enclosed by a pair of paleæ. The commonest form resembles the grain of an oat inasmuch as the caryopsis is comparatively lightly gripped by the paleæ, and it may be freed if the seed is exposed to exceptionally rough handling during the cleaning processes which bulks of seed have to undergo. Practically the only grass seed in which naked caryopses occur in abundance is that of Timothy grass. When fully ripe the seeds are detached from the inflorescence by the fracturing of the rachilla. This breaks immediately below each seed, with the result that the joint carrying the seed above remains attached to it (Fig. 32). In some few cases the breakage occurs immediately below the glumes,

and the seed then consists of the complete spikelet. The grasses in which this occurs have single-flowered spikelets, *e.g.*, foxtail and sweet vernal, or two flowers of which one only sets grain as in Yorkshire fog.

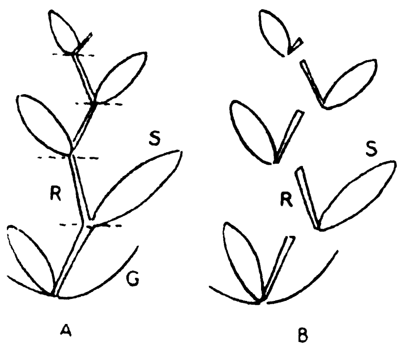


FIG. 32.

A, a complete four-flowered spikelet of a grass; B, the same spikelet with the seeds separated from one another (diagrammatic); G, the glumes; R, the rachilla; and S, the seed.

Size provides one of the more important characters used in the identification of seeds. The extremes amongst the grasses used in farming practice are tall oat grass with a length of 6 to 10 mm., and fiorin, which only measures 1·5 mm. Their dimensions are reflected in their weight: one pound of the former contains 130,000, and of the latter 5—6,000,000 seeds. The number of seeds per pound is a matter of importance in deciding on the quantity to be used in making up mixtures for putting down land to grass. Data on the subject, together with the quantity necessary to sow a statute acre, are given in the following table:—

	Number of seeds per lb.	Quantity necessary to sow one acre. Millions of seed.	Weight lbs.
Perennial rye grass	237,000	8	35
Italian rye grass	228,000	8	35
Timothy	1,070,000	12	11
Tall oat grass	130,000	6	46
Golden oat grass	1,300,000	12	9
Cocksfoot	460,000	8	17
Tall fescue	220,000	6	27
Meadow fescue	263,000	8	30
Hard fescue	500,000	12	24
Sheep's fescue	1,170,000	18	15
Crested dog's-tail	761,000	12	16
Meadow foxtail	460,000	8	17
Fiorin	5,000,000	10	2
Sweet vernal grass	800,000	12	15
Smooth-stalked meadow grass ...	2,130,000	15	7
Rough stalked meadow grass ...	2,300,000	15	6½

The awns, when present on the paleæ, provide a useful series of characters for the identification of grass seeds Where they are absent the tips of the seed are blunt (*e.g.*, the meadow grasses and perennial rye grass), or rather sharply pointed, as in cocksfoot, and crested dog's-tail. If the point exceeds the length of the palea, the seed is described as "awned." This, however, is a somewhat conventional minimum, the awns frequently being several times

the length of the palea. They may be borne at the apex of the seed or "terminal," halfway down its back or "dorsal," or at its base or "basal" (Fig. 33). Terminal awns are characteristic of Italian rye grass, some of the small fescues, barley grasses, and of the bromes, in which they spring from between two distinct teeth. Dorsal and, at the same time, twisted awns occur in tall and golden oat grass, and the wild oat, whilst basal awns are found in the genus Aira (hair and tussock grasses). The awns on the seeds of sweet vernal grass spring from the glumes, the thin papery paleæ within them being awnless.

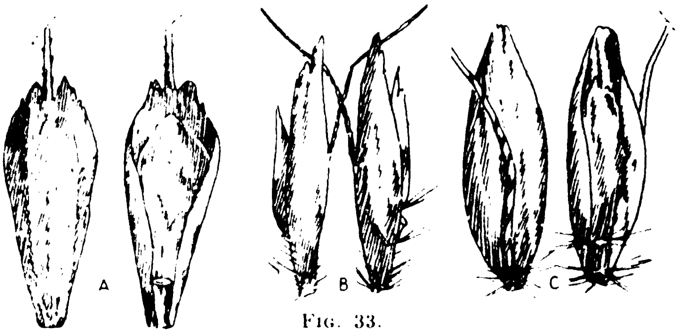


FIG. 33.

A, seeds with terminal awn : *Bromus mollis*.
B, seeds with dorsal awn : *Avena flavescens*.
C, seeds with basal awn : *Aira flexuosa*.

The paleæ forming the outer coat of most of the grass seeds are glabrous, or the hairs on them are so feebly developed as to be invisible without the aid of a lens, but in a few species, such as golden and tall oat grass, the seeds are distinctly hairy, owing to the presence of tufts of bristles at the base of the paleæ and on the rachilla. In the meadow grasses also a web of soft hairs springs from the lower parts of the paleæ, but only traces of it are visible in commercial samples, owing to its removal during cleaning operations. The seeds consequently do not aggregate into woolly flocks as they otherwise would. The soft velvety surfaces of the seeds of meadow foxtail, sweet vernal grass, and Yorkshire fog are due to the hairs on the persistent glumes.

The dispersal of grass seeds is largely effected by the wind. Many are well adapted for this purpose by their small size, by their flattened shape, or by the presence of a web of hairs which serves as an efficient float. Strongly awned seeds, however, are often distributed by animals : the awns, which are often rough owing to the development of rows of minute teeth on their edges, catching readily in the coats of sheep. Imported wool often contains a striking assortment of the seeds of such "burr" grasses which have to be removed before manufacturing operations can commence, whilst seeds of the sterile brome grass and of the barley grasses are common in the fleeces of English sheep.

The germination of grass seeds is similar to that of the cereals (Fig. 34). The germinating capacity, too, is nowadays comparable with that of well-harvested wheat or barley, and seed guaranteed by the vendors to germinate from 90 to 99 per cent. is generally purchasable. When it is realized that owing to the uneven ripening of the inflorescences of many species, much unripe seed is inevitably harvested which has then to be separated mechanically from the fully developed seed, the results are remarkable. The seed of the more generally used species, too, is now being marketed cheaply. That of perennial rye grass, with a guaranteed purity of 99·4 per cent. and a germinating capacity of 94 per cent., can be bought at fourpence a pound, or at the rate of approximately 60,000 seeds for a penny.

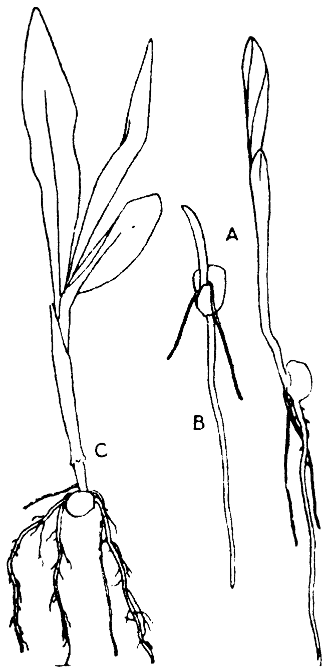


FIG. 34.—GERMINATION OF MAIZE.

A, the first sheathing leaf surrounding the first green foliage leaves; B, the primary root; and C, adventitious roots beginning to develop from the lowest node.

Stems and Foliage.—The stems, or "culms," of the grasses are rounded in section and hollow, except at the clearly defined nodes from which the leaves spring. Immediately above each node of the young stem is a region of tissue capable of active growth. The elongation of the stems is consequently brought about, as a rule, exceedingly rapidly, through the agency of some five or six intercalary growing zones instead of by a single terminal growing point, such as occurs in dicotyledonous plants. If a sharp jerk is given to a young stem of, for instance, wheat at the stage at which the ear is beginning to emerge, it will break at one of these zones, generally the uppermost or youngest. They form obvious weak places, but the stem is stiffened and damage in rough weather is prevented by the more rigid leaf sheaths, which completely surround them. The tissues thicken and harden when the full heighth of the stem has been reached, but even then they are capable of a limited amount of growth. Thus if a culm is bent over to the ground, as happens when a cereal or grass crop is laid, the tissues on the sides of the nodes nearest the soil elongate somewhat whilst no changes occur on the opposite side. A series of bends is thus formed which are of decreasing intensity, the strongest being at the basal node, the weakest at the uppermost. The uppermost internodes are thus carried back to a vertical position.

Grass stems, with the comparatively rare exceptions provided by a few tropical species, only form new branches, or "tillers" from the lowermost nodes. If all of these grow upwards, as they commonly do, the plants have a characteristic tufted habit of growth. But in a number of species the stems push out in a direction parallel with the soil surface, forming either superficial runners or "stolons" or subterranean "rhizomes" (Fig. 35). The creeping bent grass (*Agrostis stolonifera*), with its runners three or four feet in length, and the well-known couch grass (*Agropyrum repens*), are excellent examples of these two types of stems. Each node of either a stolon or a rhizome can give rise to an adventitious root system, and as the axillary bud present at the base of each leaf sheath is capable of development, a series of new plants, attached

FIG. 35.

Rhizomes of the smooth-stalked meadow grass.

for the time to the parent plant, arises. Such grasses have a matted rather than a tufted habit of growth, and they play an important part in the formation of the close sward so characteristic of the pasture lands of this country. This vegetative reproduction is aided in rhizomes by the storing of reserve foods in their tissues. Any bud-bearing portion which is broken off during such operations as ploughing or harrowing can, under suitable conditions, start into growth, and by drawing upon this supply of food, rapidly establish itself as an independent plant. In the onion couch (*Arrhenatherum avenaceum*) the development of the rhizome for this purpose is particularly marked. Each of its short internodes is so strongly swollen that the rhizome has the appearance of a string of beads (Fig. 36). The bulb-like "beads" enclosed in their papery leaf bases, the only part of the leaf which develops below ground, separate readily and quickly give rise to new plants.

The habit of some of the commoner agricultural species of grasses is as follows :—

Tufted.	*Stoloniferous.*	*Rhizomatous.*
Rye grass.	Yorkshire fog.	Couch grass.
Timothy.	Bent grass.	Foxtail.
Tall fescue.	Rough-stalked meadow grass.	Red fescue.
Cocksfoot.		Smooth-stalked meadow grass.
Crested dog's-tail.		

The leaves of the grasses are invariably arranged in two ranks. This feature separates them at once from such members of the sedge family (Carex) as the carnation grass (*C. panicea*), in which the grass-like leaves are arranged in three ranks on a stem which is triangular, instead of rounded, in section. The long, narrow leaves may be superficially much alike, but the comparison of a few species

FIG. 36. RHIZOMES OF THE ONION COUCH. (*Arrhenatherum avenaceum var. bulbosum.*) Showing the bulb-like internodes.

discloses differences in their shape, and the extent of the development of portions of them which provide reliable characters for their identification in the absence of their flowering shoots. The leaf consists of a blade or lamina, with its veins arranged in parallel, and a well-developed sheathing base. Petioles are wanting in all of our native species, and rare elsewhere. At the junction of the blade and its sheath is a thin papery outgrowth pressed close against the stem. This is the ligule. In some grasses such as cocksfoot, rough-stalked meadow grass, and bent, it is long and torn at the apex ; in others, such as smooth-stalked meadow grass and couch grass, it is short and blunt ; whilst in tall fescue its development is so slight that the technical description is " wanting."

The base of the blade where it passes over into the sheath may have its margins prolonged into claw-like processes, often distinctively

coloured pink or yellow, which more or less completely embrace the stems. These "auricles" may, however be wanting. They are strongly developed in barley, for instance, and lacking in oats, whilst in sheep's fescue they are short and erect.

A comparison of the leaf-blades of a number of species discloses differences in their shape which are sufficiently characteristic and constant to be useful for purposes of identification, though they are difficult to describe accurately. The best marked features are (*a*) leaf distinctly broadest at the base as in cocksfoot; (*b*) tapering both to apex and base as in tor grass; (*c*) almost parallel sides tapering rather suddenly to a point, as in the meadow grasses; and (*d*) needle-like or "subulate."

The surface may be bright green or blue-green in colour, smooth or hairy, and not uncommonly harsh and rough to the touch —"scabrid." The roughness is due to the presence of minute teeth set on the ribs, and especially on the margins, so that they point either in an upward or downward direction. The upper surface may be flat, as in the meadow-grasses and cocksfoot, or more frequently thrown up into a series of parallel ridges, formed by girder-like masses of sclerenchymatous tissue situated immediately above the vascular tissue of the veins (Fig. 37). A ridged leaf, if

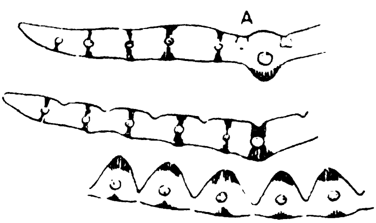


FIG. 37.

Transverse sections of a ribless leaf, *Poa pratensis* (A); a leaf with flat ridges, *Alopecurus pratensis* (B); a strongly ribbed leaf, *Aira cæspitosa* (C); and a needle-like leaf, *Festuca rubra* (D).

The circles show the position of the vascular bundles and the shaded portions of the sclerenchyma.

held up to the light, shows an alternating longitudinal series of light and dark striæ, the light portions being the thin strips lying between the thick portions traversed by the veins. The ridges are very prominent in rye grass, crested dog's-tail, creeping bent grass, foxtail and tall fescue, and less prominent in Timothy grass, couch grass, and tall oat grass. The unfolded leaves of the young shoots of the ridged species are generally "convolute," or rolled in the manner of a cigarette paper, whilst those of the ribless grasses are "conduplicate," or folded along the line of the midrib like the covers of a book. The shoots themselves are consequently rounded or flattened in shape. The blades tend to roll or fold under dry conditions but flatten out again in a moist atmosphere, except in the case of the species with needle-like foliage, in which the rolling

is permanent (Fig. 37). The stomata are usually distributed over both surfaces of the ridgeless leaves and on the slopes between the ridges on the upper surfaces of the ridged leaves. As a consequence when rolling takes place they open into a more or less enclosed space, the atmosphere within which soon becomes water-saturated, with the result that the rate of transpiration falls off or may even cease entirely. Such grasses can therefore use the available water supply economically and so tide over brief spells of drought.

The surface of the leaves of the more important agricultural species is glabrous, or even in some cases, such as rye grass, highly polished. A few have foliage covered with soft hairs. This also prevents an excessive loss of water by transpiration by retaining a layer of water-saturated air in the neighbourhood of the stomata. Examples are provided by Yorkshire fog, soft brome, sweet vernal, and golden oat grass.

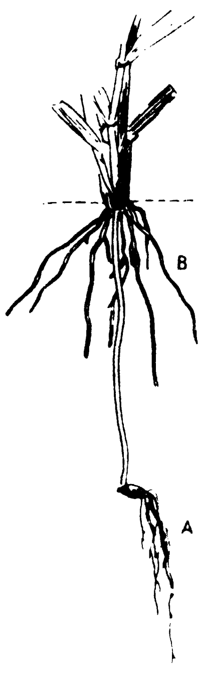


FIG. 38.
Young wheat plant: A, the primary roots which have ceased to function, and B, the adventitious root system developed from the lowest node.

The sheathing leaf base is most commonly tightly rolled round the stem, but in the meadow and brome grasses its edges fuse together so that it forms a complete cylinder. This characteristic is difficult to observe satisfactorily, for the closed sheath may be split by the rapid growth of the enclosed stem or on the emergence of the inflorescence. It is the only part of the leaf which develops on rhizomes. In couch grass the overlapping sheaths of the young shoots are thickened and form a hard, sharply pointed bud, which makes a peculiarly effective soil-piercing structure.

Root System.—The roots of the grasses form a close, fibrous mat immediately below the soil surface. They do not range deeply in the soil, and the depth to which they penetrate is determined largely by its physical conditions. On badly aerated clay soils most of the roots will be found in the top two inches, whilst in loams and the lighter types of soil they may push down to a depth of six inches or so. But even so the sods cut for turfing purposes from these more porous soils contain the greater part of the root system. This relatively shallow rooting habit is characteristic of all of the species of agricultural importance, and none of them is capable of making much use of the moisture present in the deeper layers of the soil. They are consequently distinctly susceptible to the effects of drought.

The root system, like that of the cereals, appears to be wholly adventitious. The roots formed during the germination of the seeds

serve to establish the young plants, and as new roots develop from the nodes of each of the young shoots they cease to function (Fig. 38).

Growth Habit.—Grasses may either die out after producing a crop of seed or they may live for a long but undetermined period. Those of the first group, the "monocarpic" species, may seed in their first or second season of growth. Seed of Italian rye grass, the only one of any agricultural interest, may be harvested in the year of sowing or the plants may over-winter and seed the following year if they start into growth late in the season or if their development is checked by the competition of the cereal crop with which they are often grown. Others, such as soft brome grass, only produce clumps of foliage during the first season and flower in the following year. The terms "annual" and "biennial" are used to distinguish between the two habits. The length of life of the longer-lived species, or "perennials" varies much with the conditions under which they grow. Tall oat grass does not appear to be a very persistent species under ordinary agricultural conditions and the undoubtedly lasting perennial rye grass may soon die out on light, sharply-drained soils. The life of individual plants of those species capable of reproducing themselves vegetatively would appear to be an indefinitely long one.

Their rate of growth, like that of vegetation generally in temperate regions, is dependent on the seasons. At the beginning of the farming year, in October, it slows down and, except in mild seasons in the southern parts of the country, it practically ceases with the coming of winter. In severe weather the foliage may die off almost completely. There are differences though in the hardiness of the various species, but practically the only permanent grass which is resistant to winter burning is perennial rye grass. After lying dormant through the winter, growth begins again in the spring, the various species starting into growth at different periods. With the coming of warmer weather and especially of an ample rainfall, the rate of growth accelerates, and by the end of May or the beginning of June, the date depending on the district and the season, most of the various species, if ungrazed, rush into flower. Growth then slows down and the subsequent production or aftermath depends very largely on climatic conditions. This seasonal habit of growth and also the dependance of the amount of the crop on climatic conditions constitute the graziers' chief difficulty. He can only guess the head of stock required to keep a given area adequately grazed down and, in the event of an under-estimate, much of the produce may be wasted through inability to utilize it at its best stage of development. This is at the stage when the leaves are some three or four inches in length as the nutritive value falls off rapidly as the shoots begin to pass over into the flowering stage (p. 493). The surplus must then be got rid of either by bringing in more stock or by mowing.

The average production of permanent grassland when measured

in the form of hay is approximately one ton per acre but, under favourable growth conditions and where attention is paid to manuring, double this quantity can easily be obtained. The yield depends upon the climatic conditions more than anything else and a long dry period in the spring is almost invariably followed by scanty crops whilst a late summer drought will prevent the production of an appreciable aftermath. In spite of the fact that the grasses can, to a great extent, guard against the ill-effects of excessive transpiration, there is no other crop so intolerant of dry conditions and so likely to fail completely when they occur. The rolling or folding of their foliage serves at the most to carry them safely through comparatively short dry periods, and after a long spell of hot, sunny weather the plants may even be killed to the ground. As a consequence of the dependance of the grasses on an abundant rainfall meadows and pastures are more numerous and more productive in the western and northern parts of the country than in the drier eastern and southern portions. Deficiencies in the rainfall may, however, be offset by higher water-tables providing a continuously moist root range. The plants then grow steadily throughout the spring, summer and autumn and provide the grazier with an unusual uniformity of production. Fields in which this occurs earn the reputation of being good grazing land. Or again such conditions can sometimes be secured by irrigation. Where this is practised, as it is in the water-meadows of Wiltshire and Dorsetshire, the yields of herbage, almost irrespective of the weather, are far in excess of the average and moreover the useful period of the fields is prolonged by the starting into growth of the grasses at an earlier date than usual. This control of the water supply is, however, only satisfactory when the soil conditions permit of thorough drainage, for water in excess with the consequent deficiency of the air supply of the soil is detrimental to the growth of the better grasses. Where this occurs their place is apt to be taken by tussock grass (*Aira cæspitosa*), rushes and such sedges as carnation grass.

The species of agricultural importance are, for the most part, capable of growing under a wide range of both soil and climatic conditions, though few of them are found in much abundance outside of the limits of enclosed land. Some show a sufficiently marked preference for the conditions obtaining on, for instance, chalky or clay soils to make them the dominant species of the associations occurring in such situations, but this does not imply that they will not be found on gravelly or loamy soils. All of these soils, indeed, tend to carry their more or less distinctive grass flora though the differences may be not so much in the actual species present as in their proportions. Very distinctive floras occur on the soils overlying the chalk, on which the smaller fescues and crested dog's-tail thrive, and again on the sour soils on which creeping bent forms the bulk of the vegetation, but on the soils ranging from light loams to the heavy clays the floras have much in common. Where species show a decided preference for any particular type of soil

the fact is mentioned in the detailed descriptions of each which follow. Its importance, when the problems of grassing down land have to be considered, is obvious, for if any species will not thrive naturally it is waste of effort to try to establish it permanently.

The soils which are especially favourable for the development of good grassland are the well-drained loams, preferably those on the heavy side. The best meadows and pastures are to be found on them. Good second-class grassland occurs on the clay soils of the midland and, to a less extent, of the eastern counties, though the permanent grass of perhaps most of the heavy clay lands falls far below the average in productivity. The grassland of chalky soils is usually better fitted for grazing purposes than for the production of hay, whilst sandy and gravelly soils are characterized by producing a thin, low-yielding type of turf.

The flora depends also on the use which is made of grassland. If a field is mown year by year and only the aftermath grazed it tends to differ from that of a field which is systematically grazed. The taller grasses which form the bulk of the hay crop shade the dwarfer species, the white clover and such rosette-forming plants as ribwort, sufficiently to check their growth and finally to suppress them. The herbage thus tends to consist mainly of the strongest growing species, such as cocksfoot, meadow fescue, foxtail, etc. Where grazing is practised these vigorous growers are kept under control and the finer species and the clover have a better chance of developing. Each system thus produces its own particular type of herbage. There is, consequently, much to be said for setting aside part of the grassland on a farm for mowing and a part for grazing. This is practised to a certain extent and first-class pastures are rarely mown, or again fields with too soft a surface to carry stock early in the year are reserved for hay. But a common method of management is to mow and graze in alternate years.

Grass Species.—RYE GRASS (*Lolium perenne*) (Fig. 39) is one of the most widely distributed species in this country and where it occurs it is generally in abundance. It is an unfailing constituent of good pastures, often contributing more to their herbage than all of the rest of the grasses and clovers taken together The grass is a lasting perennial on good soils but on light soils, especially in dry districts, it tends to die out after a few years. The abundant herbage is produced over a long period and even during the late autumn months it makes an appreciable growth. Hard treading damages it less than most grasses, with the result that it is often the only species to be found near gate-ways or on footpaths across fields.

The seed of rye grass is cheap, rarely contaminated with weed seeds and, when fresh, it usually has a satisfactory germinating capacity. This, after a normal seed harvest, is generally about 85 to 90 per cent. A high bushel weight is usually a good index of the quality of a seed sample. The best grade weighs 28 lb. to the bushel, the next 26 lb. They owe their weight to the fact that all of the caryopses within the paleæ are well filled. Where they are

only partially developed, either through immaturity at harvest or through the feeble development of the crop, the seeds, though still apparently of full size, have a high ratio of chaff to grain and consequently a low bushel weight. In such samples the germination percentage cannot be expected to be high. Further, owing to the failure of feebly-sprouting seeds to produce established plants, their purchase may not be economical even when full allowance is made for a somewhat defective germinating capacity.

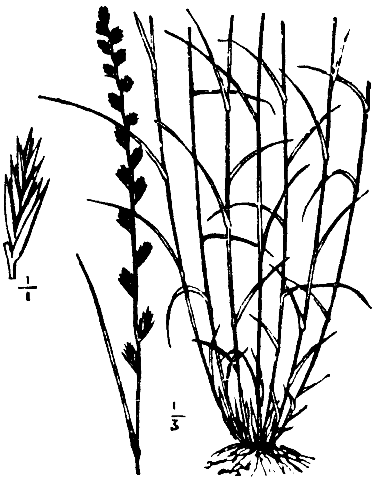


FIG. 39.—PERENNIAL RYE GRASS, *Lolium perenne*, L. With a single spikelet on the left.

FIG. 40.—ITALIAN RYE GRASS, *Lolium Italicum*. With a single spikelet on the right.

Rye grass seed forms the basis of almost all mixtures for putting land down to grass whether temporarily or permanently. It is one of the few kinds of grass seed which can be counted upon to germinate and establish itself under conditions which are not altogether ideal for these purposes. The young plants grow rapidly and under favourable conditions produce a good yield of herbage in their first year. The maximum production is generally reached in the following year and from thence onwards a high level is maintained whenever the soil and climatic conditions are suitable.

ITALIAN RYE GRASS (*Lolium Italicum*) (Fig. 40) though not a native species has come to play an important part in grassland husbandry. It lacks the perennial habit of all of the other grasses of agricultural importance and, at the most, it is of biennial duration though occasionally it may appear to have a longer life period owing to its having re-seeded itself. On moist, fertile soils, especially such as those irrigated with sewage, it is capable of producing a greater bulk of herbage than any other species of grass which can be cultivated in this country. The yields under the more ordinary conditions of farming are also high. The grass has the valuable

characteristic of withstanding the effects of frost and so remaining winter green, and as it starts into growth early in the spring it provides a certain amount of young grazing material when practically all of the other grasses are in a dormant condition.

It is readily established from seed and the plants rapidly reach their maximum productivity. The outstanding use of this grass is for sowing in association with clovers for the formation of short leys. It is also frequently used in mixtures for long leys and permanent grassland. Its employment for this purpose requires consideration for its vigorous growth tends to stifle the slower growing permanent species. If sown with the object of securing a heavier yield of hay during the first season's growth of a long ley, or especially of permanent grass, the seed rate should not exceed one pound per acre. With a heavier seed rate the risks of lodging in wet weather increase and, moreover, when the plants die out a greater area of bare land has to be colonized by grasses which only reach their maximum development comparatively slowly. Reliable seed with a germination capacity of 85 to 95 per cent. can always be obtained. But the responsibility for its purity must be placed wholly on the vendor, for an inspection of a seed sample fails to disclose whether it consists of Italian rye grass only or of a mixture with perennial rye grass. The one visible point of difference between the seeds of these grasses is that that of the Italian has a slender terminal awn. During the cleaning operations to which the bulks are subjected, this is unavoidably removed from a large percentage of the seed.

Cocksfoot (*Dactylis glomerata*) (Fig. 41) is probably the highest yielding of the various species occurring in grassland. It is widely distributed, but in the best pastures it only occurs, at the most, in small quantities. In second-class pastures it is frequently the dominant species. The grass starts into growth early in the spring and the young shoots are readily grazed by all kinds of stock. If not grazed the foliage becomes harsh and unpalatable and the plants, especially when widely spaced, grow into rough, compact tufts which may unprofitably occupy a large proportion of the grazing surface. Where, owing to understocking, this has occurred the useless herbage should be mown or a steady deterioration of the field may set in. As a meadow grass cocksfoot produces an abundance of coarse hay.

Cocksfoot shares with rye grass the useful characteristics of being readily established from seed, of permanency and of producing bulky crops within two seasons of its sowing. It is consequently largely used in mixtures for forming both temporary and permanent grassland and especially for temporary leys on poor soils on which rye grass is known to be lacking in lasting capacity. Were it not for the fact that it requires careful management it would generally be considered to be an equally valuable species.

Though seed can easily be produced in this country or gathered in quantity on waste land, commercial supplies are imported mainly from New Zealand and Denmark.

TIMOTHY GRASS (*Phleum pratense*) (Fig. 42) has a more limited range than either of the preceding species and though poorly grown specimens can be found on most of the cultivated grass fields of this country it only thrives on deep fertile loams and clays. The fact that it often grows luxuriantly, with its inflorescences reaching to a height of five feet, on wet, uncultivated land at the edges of swamps is an index that moist conditions are particularly favourable for its development. It makes little growth and soon dies out if sown on sharply-drained soils in dry districts.

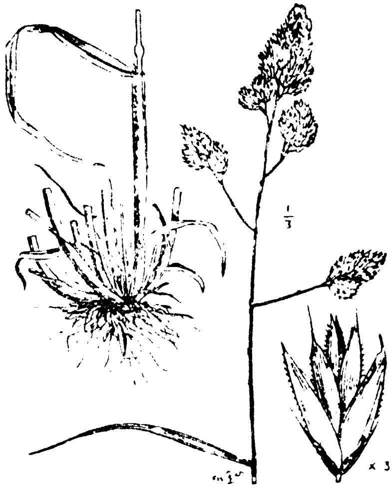


FIG. 41. COCKSFOOT, *Dactylis glomerata* L. With enlarged spikelet on the right.

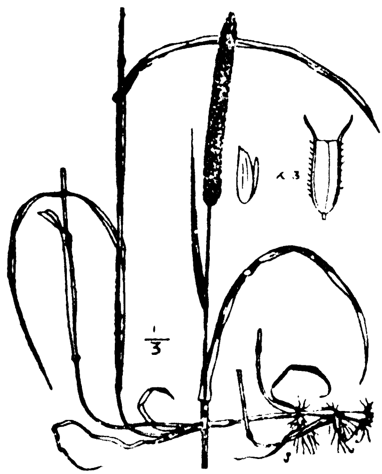


FIG. 42. TIMOTHY GRASS, *Phleum pratense*, L. With enlarged spikelet and, on its left, the contained floret.

Timothy grass reaches its maximum productivity in the first or second year after sowing and yields an abundance of foliage. Though late in flowering its characteristic broad, bluish-green leaves are produced early in the spring and they continue to develop well on into the autumn when the plants have been kept grazed or an early cutting made for hay. As the flower stems soon become hard meadows containing the grass in quantity should be mown as soon as possible after its ears emerge from the sheaths.

The seed is abundant and inexpensive, and it is generally of excellent quality. It is included in most mixtures for the formation of permanent grassland with the exception of those designed for use on chalky soils or those overlying porous sands and gravels. The seed is also used for mixtures for leys even when these are to remain down for a single season only. The grass may also be grown. as it is in America, as a pure crop.

FOXTAIL (*Alopecurus pratensis*) (Fig. 43) is perhaps less widely distributed in this country than any of the other grasses of great

agricultural importance. It occurs in the greatest abundance on well-drained fertile loams and neither water-logged nor unduly dry soils provide a suitable habitat for it. It starts into growth early in the season and frequently comes into flower in the milder parts of the country at the beginning of May. Meadows containing the grass in quantity consequently require to be cut at an early date. The proportion of foliage to flower shoots is high and stock graze the grass eagerly. It is thus unquestionably a valuable species. But disappointing results in attempting to establish it from seed have

FIG. 43.—MEADOW FOXTAIL, *Alopecurus pratensis*, L. With enlarged spikelet on the left.

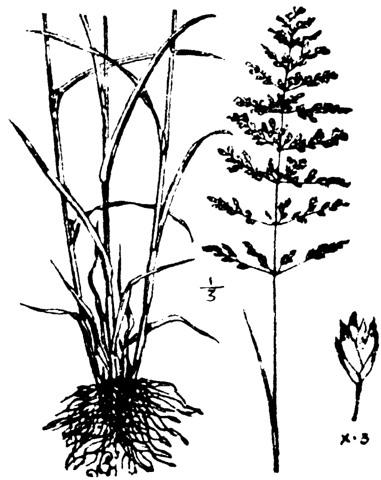


FIG. 44. ROUGH-STALKED MEADOW GRASS, *Poa trivialis*, L. With enlarged spikelet on the right.

led to a general abandonment of its use in seeds mixtures designed for either long leys or permanent grassland. The difficulties in the past were probably due to the use of seed with a low germinating capacity for in a large percentage of the seeds the caryopsis was replaced by the orange-coloured larvae of a midge (*Dasyneura alopecuri*). Refinements of seed-cleaning machinery have done away with this difficulty and seed of a remarkably high germinating capacity, when the irregular ripening of the inflorescences is taken into consideration, is now obtainable. Even now, however, a good plant is not often obtained. A comparatively late sowing, for instance in June, is said to offer the best chance of success. Fortunately, however, the grass readily establishes itself on suitable soils. This is due to the fact that the seeds are well adapted for wind distribution. They are light in weight and the flattened, connate glumes form an efficient floating mechanism.

The MEADOW GRASSES occurring in grassland in this country are of three kinds, the rough-stalked (*Poa trivialis*) (Fig. 44), the

smooth-stalked (*Poa pratensis*) (Fig. 45), and the wood meadow grass (*Poa nemoralis*).

Rough-stalked meadow grass is the most valuable of all of the bottom grasses, its short runners and fine, close growth being ideal for the formation of a closely-knit sward. The foliage is fairly abundant, relished by all kinds of stock and produced over a long season. The grass is very widely distributed and though generally to be found in the greatest abundance under somewhat moist conditions on, for instance, rich loams or in water meadows, it nevertheless succeeds well even on poor soils provided that the rainfall is adequate. On light soils it is apt to burn out in dry

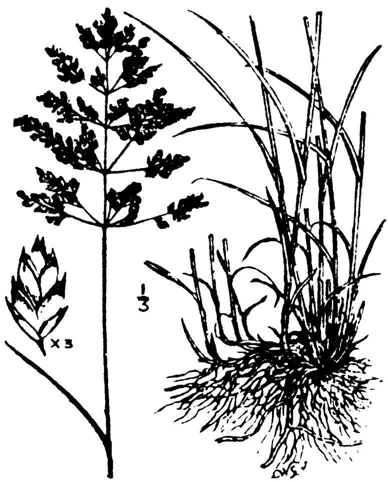


FIG. 45.—SMOOTH-STALKED MEADOW GRASS, *Poa pratensis*, L. With enlarged spikelet on the left.

FIG. 46.—DOG'S-TAIL, *Cynosurus cristatus*, L. With enlarged spikelet and, on left, two of the pectinate bracts.

weather. Under such conditions its place is taken by the rhizomatous smooth-stalked meadow grass. The wood meadow grass has a more limited range than either of these species and its chief value is to be found in the fact that it will tolerate the shading of trees more than most of the agricultural grasses.

All three are primarily grasses for grazing, for though their light, feathery inflorescences suggest a fair yield of hay, analyses of the crop show that they rarely contribute much to its weight. They are, further, better suited for permanent grassland than for temporary leys for they grow comparatively slowly and some three or four years pass before they reach the stage of maximum development.

The seed of rough-stalked meadow grass is used in the majority of seeds mixtures for permanent grassland and occasionally in mixtures for leys which are to stand for more than three years. The seeds of smooth-stalked meadow grass find a limited use on

light soils and in dry districts whilst those of the wood meadow grass are rarely included in mixtures for agricultural purposes though considerable quantities are used for forming the fine type of turf required on lawns.

The whole of the seed supply is imported, the bulk of it coming from Denmark and the United States where crops are grown for seed on a large scale. As the seeds are small and readily wind-borne the meadow grasses tend to establish themselves on fields sown down with mixtures in which they have not been included.

CRESTED DOG'S-TAIL (*Cynosurus cristatus*) (Fig. 46) is probably the most widely distributed of the grass species which are generally recognized as being agriculturally valuable. It thrives not only on the fertile loams on which the best grasslands are to be found but also on heavy clays and on the light soils overlying the chalk. On either of these extreme types it may even be the dominant species. Its yield of herbage is small compared with that of rye grass or cocksfoot but its deficiencies as a meadow grass are compensated for by its merits in pastures. It is one of the relatively few species of much value for forming a close turf. Cattle and sheep graze it closely, generally, however, leaving the flowering shoots once the inflorescence has shot, with the result that the grass continuously seeds itself down. The wiry culms persist through the winter and give fields in which dog's-tail is abundant a very characteristic appearance.

A "take" of this grass is more easily secured than that of any other bottom grass, and though it is of relatively little use in leys its seeds should find a place in the majority of mixtures for the formation of permanent grassland. On heavy soils, such as those of the boulder clays and again in districts subject to drought, its use is almost essential for it can be counted upon to take the place of perennial rye grass if this species should fail to persist.

FIORIN, CREEPING BENT GRASS or WATER GRASS (*Agrostis alba*, var. *stolonifera*) (Fig. 47) is the most widely distributed of the grasses of agricultural importance. It has the valuable characteristic of tolerating conditions in which few other species can exist. Under such circumstances it dominates all others. This is the case for instance, on the sour soils of the millstone grit and the coal measures in Yorkshire where 90 per cent. or more of the herbage of pastures often consists of this species. It occurs, too, on light, sharply-drained soils and also on heavy, impervious clays. On either of these extreme types it tends to become a dominant species. On the other hand creeping bent grass is a common constituent of the flora of most of the best pastures in this country, where it is generally more abundant than might be expected from a casual examination. The grass is a typical mat-forming species which spreads widely and rapidly by stolons. These, by rooting down at the nodes wherever the conditions are favourable, help greatly in the formation of a close sward. The young growth, especially when associated with other species, is well grazed but the older shoots are rejected when other herbage is available. Thus, on land which is not

systematically closely grazed, creeping bent is apt to get out of hand. It then forms the bulk of the bleached grey "fog" which, in the winter months, covers so much of the pasture land on the heavier soils. As its presence is prejudicial to the development of the young grass shoots and clover in the spring, the use of spike harrows to tear off the mat becomes part of the routine of managing undergrazed pastures in which the species is abundant.

Seed of this species is rarely used in the mixtures employed for the formation of permanent grassland. The grass, however, is frequently over-abundant on newly sown fields. Its occurrence may be explained either by the difficulty of killing the grass when preparing the land for sowing or by the fact that its minute seeds, of which there are about 5,000,000 in a pound, are readily wind-borne.

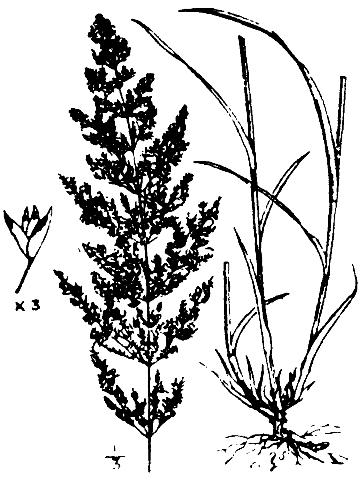


FIG. 47. FIORIN, *Agrostis alba*, L., var. *stolonifera*. With enlarged spikelet on the left.

FIG. 48. TALL OAT GRASS, *Arrhenatherum avenaceum*, L. With enlarged spikelet on the right.

TALL OAT GRASS (*Arrhenatherum avenaceum*) (Fig. 48) is a common hedgerow grass and a not uncommon constituent of the herbage on most of the medium types of soil, but on poor infertile soils or wet clays it is generally absent. In favourable circumstances it gives heavy yields of foliage which, however, is not grazed when other herbage is available. The grass is largely grown on the Continent, often in pure culture. Here, however, little attention is now paid to it, though at the beginning of the century its growth was generally recommended. As a constituent of permanent grassland it is of special use in shaded situations. But it is not a lasting species on land which is kept heavily grazed. It finds its chief use in temporary leys put down for the production of hay. Its high yielding capacity under such conditions is a useful asset, especially as the hay is said to lack the bitterness characteristic of the fresh

foliage. But it is an expensive grass to introduce as the seeds are large, compared with those of most other species, and consequently a heavy seed rate is essential.

THE FINE FESCUES are classed as a single species, *Festuca ovina*, in Bentham and Hookers' British Flora, though Linnæus, and with him most agriculturists, look upon hard fescue (*F. duriuscula*) and red fescue (*F. rubra*) as distinctive species.

All three have subulate or needle-like foliage. That of the sheep's fescue (*F. ovina*) grows in dense tufts, whilst that of the red fescue forms spreading mats owing to the development of rhizomes. Hard fescue has flattened leaves on the flowering shoots but the radical leaves are all subulate.

SHEEP'S FESCUE (Fig. 49) is a grass of dry, open situations, such as chalk downs, mountain pastures, or gravelly and sandy soils. Its dense tufts of wiry looking foliage often form the bulk of the grazing in such situations. Hard fescue (Fig. 50) has much the same

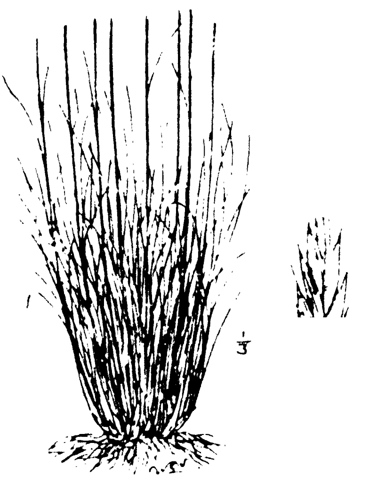


FIG. 49. SHEEP'S FESCUE, *Festuca ovina*, L. With enlarged spikelet on the right.

FIG. 50. HARD FESCUE, *Festuca duriuscula*, L. With enlarged spikelet on the left.

distribution, but in addition the grass is found in good meadows and pastures in which it forms a useful bottom grass. Red fescue is also a fairly generally distributed bottom grass and it is further found in dry situations, especially in the neighbourhood of sea coasts.

None of the species are suitable for temporary grassland, though each of them can be usefully employed when forming permanent grass under the conditions indicated by their usual habitats. The only difficulty that arises is that seed of the true red fescue is scarce. Its place is taken by seed of a New Zealand variety of *F. rubra* known commercially as "Chewings' fescue." This lacks the

rhizomatous habit of growth and is consequently of doubtful value as a bottom grass.

MEADOW FESCUE (*Festuca pratensis*) (Fig. 51) is an outstanding species on much of the best grazing land in this country. It is abundant, for instance, in the Aylesbury district and again in the Vale of Berkeley. But it is somewhat limited in its distribution and it only thrives on deep, fertile soils and on well-drained clays. Though it appears to be intolerant of stagnant water in the soil, it is an almost universal constituent of the herbage of water-meadows where, to a great extent, it takes the place of perennial rye grass. The grass produces a large quantity of succulent herbage, valuable either for grazing or hay making. It flowers late in the season and, except in years of drought, continues to grow until late in the autumn. Where it occurs, it rivals perennial rye grass in value.

FIG. 51.—MEADOW FESCUE, *Festuca pratensis*, Huds. With a single spikelet on the right.

FIG. 52.—SWEET VERNAL GRASS, *Anthoxanthum odoratum*, L. With enlarged cluster of three spikelets on the left.

In some parts of the country it has proved more or less impossible to establish this species, either temporarily or permanently. It should therefore be sown only under conditions in which it is known to thrive. These will often include boulder clays which, if not water-logged, suit the grass excellently.

TALL FESCUE (*Festuca elatior*) may be described as a particularly vigorous form of meadow fescue which is, indeed, from a botanical standpoint, a variety of it. It forms large tufts on moist clays and loams and it may also be found on lighter soils if the water supply is adequate. In spite of its coarse appearance the foliage is well grazed. The culms become woody and brittle as the seed ripens

but this is not a serious drawback to its use as flowering occurs so late in the season that they are usually cut before this stage is reached.

The species is particularly valuable on soils which are normally too moist to carry the majority of the good agricultural grasses and its seed can be sown with advantage on poorly-drained clay and fen soils. The young plants grow slowly and some four seasons pass before the stage of maximum productivity is reached.

SWEET VERNAL GRASS (*Anthoxanthum odoratum*) (Fig. 52) grows on a wide variety of soils and its general distribution suggests that it is indifferent to such extremes of temperature and moisture as are to be met with in this country. It thrives best on deep, rich soils and it is a common constituent of the flora occurring on good grassland, but it also grows well on poor land and often at considerable elevations. It has a number of useful characteristics. Amongst these are included extreme hardiness, permanence and the capacity to grow in partially shaded situations. It is further the earliest of the indigenous grasses to start into growth and it often comes into flower in March in the southern parts of the country. The growth is dwarfer than that of rye grass and the plant is usually included in the general category of bottom grasses. It differs from all other English grasses in being sweetly scented and the characteristic fragrance is retained by the foliage even when made into hay. But it is bitter to the human taste and cattle certainly show no marked preference for it. The seeds of the grass, though at one time commonly used in compounding seed mixtures, are no longer in much demand. Various reasons account for this. In the first place they are expensive as they are, for the most part if not exclusively, gathered by hand. Their high cost led to their extensive adulteration with the very similar seeds of a particularly worthless annual species, *A. Puelii*, and though this practice may have ceased its ill effects persist. There is further a doubt whether it is as valuable in practice as its useful characteristics suggest it should be.

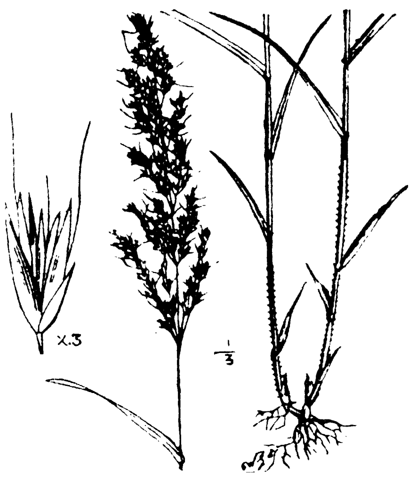


FIG. 53.—GOLDEN OAT GRASS, *Avena flavescens*, L. With enlarged spikelet on the left.

GOLDEN OAT GRASS (*Avena flavescens*) (Fig. 53) is more common in the drier south and south-eastern parts of the country than in the north and west. It is found in the greatest abundance on the

brashy soils overlying the oolite and on thin chalky soils, on both of which it may form the bulk of the herbage. The plants produce tufts of soft, silky foliage which is well grazed by both cattle and sheep. At flowering the inflorescences reach a heighth of a foot or more and though the species would generally be described as a bottom grass it contributes appreciably to the hay crop. The light, fluffy seeds are too expensive to be used generally in the preparation of seed mixtures. But owing to the readiness with which they are dispersed by the wind, the grass establishes itself naturally when the circumstances are favourable for its growth. The young plants grow slowly and the maximum yield is not reached before the third season's growth. Golden oat grass is consequently of comparatively little value for temporary leys.

Seed Production.—Most of the descriptions of the common agricultural grasses to be found in floras stress the fact that they are very variable plants. To what an extent they vary is only realized when a detailed study of any species is made either by observing large numbers of specimens as they grow in the fields or, better still, by collecting and growing them especially for comparison. If a collection of rye grasses is made striking differences will be observed in such features as the size and the width of the inflorescences, in the number of flowers in the spikelet and in colour. Differences in habit will also be obvious, some plants growing far more strongly than others or having a looser, less tufted mode of growth. Differences such as these have been recognized by the systematists whose business it is to classify plants so that they may be identified with certainty, and the tendency nowadays is to distinguish the most striking forms as "varieties" of the species. In some species, such as *Agrostis alba* or *Festuca rubra*, many such varieties are now recognized in floras. These morphological differences are, however, of relatively little importance from a purely agricultural point of view. Those whose concern it is to cultivate the plants have to pay more attention to such points as earliness or lateness in flowering, the proportion of leaf to stem, the capacity to resist adverse influences such as drought, excessive rainfall or extreme cold, the resistance to various diseases, etc. In any collection of a single grass species differences in these characteristics, as clearly defined as those of a morphological nature, will be observed. Moreover, as a rule, the wider the range over which the collection has been made, the more striking these differences will tend to be. The fact has to be recognized then that the grass species is not a rigidly defined type. It is rather an aggregate of a large number of more or less readily distinguishable "forms." *

It is evident that all of these forms of, for instance, rye grass cannot have the same agricultural value. Thus the requirements of a man interested in the formation of a pasture in a district with a

* The word is used here in a wide sense to include Jordanons, or little species, and botanical and agronomic varieties. The word "strain" is used to describe groups of forms.

low rainfall would not be met satisfactorily by the purchase of the seed of a form which grew exceptionally well in a wet district and seeded very freely.

Once the facts are recognized their bearing on the production of commercial grass seed becomes obvious. At present our supplies are drawn from various parts of the world. The seeds of the two rye grasses come from Ireland, Scotland and Devonshire, those of the meadow grasses from Denmark and America, those of cocksfoot from New Zealand, France or Denmark, those of Timothy grass from Scotland or Canada. For the most part crops are grown especially for seed, though some few species are gathered from naturally growing plants where they happen to be in sufficient abundance. Little is known with regard to the actual starting point of these domesticated grass crops. In Northern Ireland, where much of the supply of perennial and Italian rye grass is grown, the seed crops are raised from seed either raised locally or purchased in Scotland. All that can be said is that it is many generations removed from the plants of the meadow and pasture. Its original starting point was probably a mass selection from such a source, for the raising of stocks from a single plant is a relatively modern procedure. This implies a mixture of forms from the beginning. As the immediate result of cultivation the constitution of such a mixture tends to be profoundly modified. The most obvious change is that the free-seeding forms tend to become more abundant as each successive crop is grown. The result is a strain biassed for seed production. This automatic selective process affects many other characters. Those forms constitutionally suited for development under the climatic conditions of the seed-raising district similarly tend to accumulate. Thus in a period, which is probably short, strains specially suitable for local growth will be built up.

The consequences of this are becoming obvious in agricultural practice. Distinct differences in the types of imported cocksfoot are already noticeable. Crops grown from French and Danish seed start into growth earlier than those grown from English or New Zealand seed. They also tend to crop more heavily, at all events during their first season or two. Perennial rye grass grown from commercial stocks is becoming generally recognized as distinct from that of old pastures with the interesting result that the so-called "wild perennial," screened out as an impurity whilst cleaning wild white clover, finds a ready market amongst those who are putting land down to permanent grass. Whether comparable differences are to be found amongst the smaller grasses grown from domesticated or imported seeds is unknown. Their observation would clearly be difficult on land sown down permanently owing to the self-establishment of morphologically similar forms.

The further study, which is now in progress in several countries on the Continent, in America and at Aberystwyth, of the numerous forms to be found within most, if not all, of the agricultural grass species, indicates that the problem of providing the most suitable

type of seed is even more complicated than the facts already described disclose. After a detailed comparison of numerous forms of cocksfoot, Stapledon found that it was possible to arrange them in fairly well-defined groups, which in turn showed a correlation with the particular set of conditions under which they grew originally. A similar state of affairs is known to occur in Timothy grass, and there are indications that the phenomenon is a general one. If this proves to be the case then each distinctive type of soil and each particular complex of climatic conditions may require its special strains of all of the agricultural grasses. The provision of these under the existing conditions of seed growing has still to be faced and for the present the permanent grassing down of fields on the dry chalk and boulder clays of the eastern counties has to be effected with strains of grasses acclimatized for Northern Ireland, Denmark and New Zealand.

For fuller information on this subject, and for the identification of the grasses, the following books should be consulted :—

S. F. Armstrong. *British Grasses and their Employment in Agriculture*. Cambridge University Press. 1917.
Bentham and Hooker. *Handbook of the British Flora*. Reeve & Co., London.

CHAPTER XIII.

GRASSLAND: FORMATION AND MANURING OF.

Grassland.—The flora of meadows and pastures consists, in the main, of a number of species of grasses and clovers, but mixed with these various perennial weeds such as buttercups, ox-eye daisies, hawkweeds and plantains, are generally to be found. This turf-forming group or association of plants remains more or less constant in its constitution from year to year, provided that no great changes occur in its management. If, for instance, a field is systematically grazed to much the same extent, or mown at the same stage of growth, then only close observation will show that the flora differs from season to season. The differences are not so much in its constitution but in the relative amounts of the various species composing it. They are due primarily to differences in the climatic conditions and are most marked after periods of drought or unusually high rainfall. The flora of grassland is thus relatively stable. But it has not the stability which is associated with the more natural types of grassland, such as those of the steppes, prairies and savannahs. What constancy it has is due to man's close control. If left to itself the best grassland of this country would soon degenerate into the woodland, which is the ultimate natural flora of most of our agricultural land. The tendency to become derelict and to produce first of all brambles and hawthorn and then forest trees is always present. Mowing and grazing check

this, and the fields continue to remain under grass chiefly because the turf-forming association of plants tolerates a treatment which tends to kill off these competitors at an early stage of growth. The plants composing it owe their power of survival and their temporary dominance largely to the fact that they form an abundance of shoots at the soil level or immediately below it. Thus it does not matter how closely they are grazed or cut for a supply of buds remains to renew their growth.

The plant association remains relatively constant in composition too, because the dense mat of plants provides conditions which are unfavourable to the development of many of the common farm weeds. The annual weeds of arable land, such as charlock, poppies and groundsel never succeed in establishing themselves in turf, and they are only to be found temporarily colonizing patches on which for some reason the grasses have failed. Relatively few of the perennial weeds, such as thistles and stinging nettles, can hold their own in competition with the group of plants loosely described as "grass."

The fact that land can be left to grass itself down, often with a considerable measure of success, may at first appear to indicate that turf is an entirely natural product and that no special care is necessary for its production. A knowledge of the sequence of events when the cultivation of arable land is abandoned does not support this contention. The immediate flora of such land is derived from the perennial weeds present on it and from the seeds present in the soil. Probably the grasses would be represented by such species as couch grass, soft brome and creeping bent. The next contribution to the flora is provided by wind-borne seeds, amongst which the minute seeds of various grasses are present in abundance. These naturally sown seeds germinate in the half shade of the existing vegetation, and by quickly establishing themselves tend to crowd out the annual weeds. If now subsequent development is controlled by mowing or grazing or by the use of artificial manures, a turf will result. Its value depends on several factors, the most important of which are to be found in the nature of the soil and climatic conditions and the degree of skill exercised in its management. If left uncontrolled, however, for a few seasons, brambles and thorn inevitably establish themselves and prepare the way for the development of woodland.

The flora of a "tumble-down" will obviously be determined for the most part by the grasses seeding in the immediate neighbourhood. All of the grasses do not thrive equally well under all of the diverse conditions of soil and climate met with in this country. Though the commoner species used for the formation of permanent and temporary grassland can be grown almost anywhere on recently tilled soil, they will not necessarily continue to thrive when exposed to the competition of species better suited to the environment. On a freshly broken stretch of Dartmoor, for instance, perennial rye grass and meadow fescue temporarily produce an abundance of

herbage, but they soon give place to the peat-land flora of heathers, mat grass (Nardus) and Molinia. The fate of most of these "intakes" is summed up in the phrase: "the moor always wins."

The various soil types thus tend to have a characteristic grass flora, even although the humanly controlled factors ensuring the survival of the turf may be generally the same. The differences are determined by a great complex of factors, amongst which may be mentioned, though it is impossible to assess their relative importance with any accuracy, the chemical constitution of the soil which determines the supplies of food materials and their availability, its physical condition with its influence on the aeration of the root system and on the passage of water, the temperature, the rainfall and elevation.

Formation of Permanent Grassland.—It is generally recognized that one of the most difficult operations necessitated by the changing conditions of agriculture in this country is the conversion of arable into permanent grassland. Most of the knowledge on the subject is empirical and based on somewhat scanty data derived originally from a series of experiments carried out in Cambridgeshire and at Cockle Park during and since the agricultural depression of the nineties of the last century. In most of these, mixtures of grass and clover seeds of known constitution were sown, and the botanical composition of the herbage was determined year by year. The results can rarely be compared critically, partly because of the substantial error to which the analytical data were subject, and still more to the fact that it is almost impossible to make accurate duplicate experiments when so large a number of factors control the final result. Nevertheless, these early experiments established a number of facts which contribute substantially to an understanding of the sequence of events when the seeds of a number of diverse plants are sown together with the object of producing a lasting turf.

In the first place they show clearly at what periods in the development of grassland each of the common agricultural grasses can be expected to make its maximum contribution to the bulk of the herbage and they give further information as to the number of years some of them are likely to persist on various types of soil. They show, too, that some grasses of undoubted agricultural value, such, for example, as foxtail, are difficult to establish, and that they frequently fail entirely or only contribute a negligible amount to the total bulk of the herbage. Further, especially where the fields were kept under observation for a long period, they establish the important fact that the flora often bears little resemblance to that represented by the mixture of seeds sown originally. This is due partly to the disappearance of those species which are not lasting perennials, such as the red clovers and tall oat grass, but more especially to the appearance of species not included in the mixtures sown. These were always the grasses which were abundant in the locality.

This self-establishment is now known to be of very general occurrence. Thus the golden oat grass will almost inevitably "come in" on the brashy soils of the oolite, and even become a dominant species. On the thin soils overlying the chalk, sheep's fescue will generally establish itself quickly, and creeping bent may over-run a newly-sown field on a damp boulder clay soil even though no seeds were sown by human agency.

At the time when these experiments were in progress, the generally accepted scheme for compounding seeds-mixtures was the logical one of using, as far as possible, seeds of the species of grasses and clovers occurring in the district. But in order to secure a substantial yield of herbage at the earliest date, seeds of Italian rye grass and of the fleeting broad red clover were often included. The mixtures were consequently complicated, and sometimes included as many as twenty kinds of seeds. The proportions of the various seeds were determined from a consideration of the percentage of the area each sort should cover.

It was generally assumed, mainly on the basis of experiments carried out on the continent, that the clovers should occupy 20 per cent. of the area, the short-lived or rapidly-growing grasses another 20 per cent. and the permanent grasses 60 per cent. Within these limits the allotments to the various species were largely a matter of personal opinion. A typical prescription of the period is as follows :—

Red clover	5	20 per cent.
Alsike	8	
White clover	7	
Perennial rye grass	5	20 ,,
Timothy grass	15	
Cocksfoot	10	60 ,,
Meadow fescue	20	
Foxtail	8	
Smooth-stalked meadow grass	7	
Rough-stalked meadow grass	5	
Crested dog's-tail	5	
Hard fescue	5	

Having decided what percentage of the area was to be covered by each species, the requisite weight of seed had to be calculated. It was assumed that in the case of the larger seeds, such as red clover and rye grass, 5,000,000 would be sufficient to sow an acre, and that 10,000,000 seeds of the smaller species, such as white clover and crested dog's-tail, would be required. [At these rates each square foot would receive 115 of the larger seeds or 230 of the smaller]. The weights of these quantities were known for all of the agricultural grasses and clovers. Thus 20 lb. of cocksfoot was known to contain some 10,000,000 and 23 lb. of red clover some 5,000,000 seeds, and the requisite 10 per cent. of the one and 5 per cent. of the other would consequently be provided by 2 lb. and 1 lb. 2 oz. respectively.

But it is doubtful whether anyone succeeded in producing a turf composed solely of the species sown in their nicely specified proportions, for the experience of most experimenters goes to show that the soil, climate and management in the long run determine the constitution of the flora.

At present the mixtures in general use are characterized by their simplicity. The change is due to some extent to the necessity for avoiding an excessive expenditure on seeds. But the many failures to secure a good permanent turf with these complex mixtures has undoubtedly had some influence on it.

Before condemning the practice of using complex mixtures it should be recognized that there are several reasons which will account for their frequent failure to produce the results anticipated. One of the most important of these is to be found in the fact that much of the land put down to grass at the end of the last century and the beginning of this could not be expected to produce anything more than an indifferent turf. This is especially the case on the heavy clay lands which, on account of the difficulty and expense of working, were generally the first to be discontinued as arable. Moreover, on such soils the preparation of a tilth which will ensure the satisfactory germination of a mixture of grass and clover seeds is generally difficult and in some seasons it is impracticable. As a consequence only those components of the mixture which are capable of establishing themselves under poor conditions, such as perennial rye grass and cocksfoot, would "take," whilst the small-seeded, slow-germinating species, such as the meadow grasses and fine fescues, would fail. The "take" would consequently, from the first, bear little resemblance to that expected from a knowledge of the constitution of the seeds-mixture and would, on the whole, be characterized by a lack of the essential bottom grasses.

Another cause of failure is to be found in the use of Italian rye grass and an excessive quantity of red clover in the seeds-mixtures. These could be counted upon to provide a considerable bulk of herbage in the first season. But this was obtained at the expense of the slow-growing bottom grasses which they frequently shaded out of existence, leaving the field again to the stronger species which, for the most part, do not readily knit together to form a compact sward.

The question, too, may be raised whether suitable seeds were available for grassing down such extreme types of soils as the heavy clays and those overlying porous sands and gravels on neither of which most grasses thrive. The more or less consistent failure of such a species as foxtail may possibly be explained by the fact that the seed imported from Finland was of a different strain to that which grows so generally in this country, or again, it may have been due to faulty germination.

Typical examples of the seeds-mixtures in use to-day for the formation of permanent grassland are as follows :—

For Heavy Types of Soil.

Perennial rye grass	12 lb. per acre.
Cocksfoot	8
Timothy grass	4
Crested dog's-tail	1
Rough-stalked meadow grass ...	½
Late-flowering red clover	4
Wild white clover	1–1½

Light Sandy Soils in Dry Districts. (Rainfall below 30 in.)

Perennial rye grass	14 lb. per acre.
Cocksfoot	10
Crested dog's-tail	1
Tall oat grass	2
Wild white clover	1½
Late-flowering red clover ...	4
Trefoil...	2

Sandy Soils in Wet Districts. (Rainfall over 30 in.)

Perennial [illegible] grass	12 lb. per acre.
Cocksfoot	8 ,,
Timothy	4 ,,
Crested dog's-tail	1 ,,
Chewing's fescue	2 ,,
Wild white clover	1½ ,,
Late-flowering red clover	3 ,,
Alsike	1½

Thin Chalky Soils.

Perennial rye grass ...	10 lb. per acre.
Cocksfoot	8
Sheeps' fescue ...	1
Hard fescue	1
Crested dog's-tail ...	1
Late-flowering red clover	4
Trefoil...	
Wild white clover ...	1½

The general similarity of the seeds-mixtures will be noticed although they are intended for use over a wide range of soils. The bulk of the mixture is provided by the seeds of perennial rye grass and cocksfoot. These two species are almost always abundant in good grassland in this country and, moreover, their establishment from seed is more certain than that of most other grasses. Crested dog's-tail is, again, a particularly widely distributed and easily established bottom grass, and though 1 lb. may appear a small seed rate, a reference to the table (p. 264) will show that it provides approximately a million seeds per acre. Of the various red clovers available, the late flowering strain is the most valuable, for many of the plants will survive into the third season or possibly even later. Wild white clover now generally takes the place of commercial white or Dutch clover, in spite of the fact that its seed is more expensive. Its seeds are often present in the soil and as it responds freely to phosphatic manuring, a good plant can often be secured without having recourse to seed sowing. But the plant is too valuable to risk its non-appearance, and seed should always be

sown even if smaller quantities than those given in the prescriptions have to be made use of on account of the cost. A partial substitution of Dutch for wild white clover is not advisable, for it is lacking in permanence and there is also some evidence to show that its somewhat taller habit of growth tends to shade out the very procumbent wild form. The chief value of wild white clover is found in the fact that it quickly forms a close sward, even on difficult soils such as those on the boulder clay. These five species are supplemented by a few grasses and clovers known to thrive under the conditions indicated above each table, but no attempt is made to completely match the local flora. In place of this the self-establishment of a considerable number of species is relied on. Foremost amongst these are foxtail and golden oat grass and, except on the soils overlying chalk, the finer fescues.

The current practice is thus, to a considerable extent, a compromise between sowing land down to grass and allowing it to "tumble down." The best results would almost certainly be secured if the entry of the local strains of the commoner grasses could be expedited. This would involve the partial return to the practice of sowing locally produced seed which was prevalent a century ago when supplies of pure seeds of agricultural grasses were not commercially available. Sweepings of hay lofts, feeding troughs, rick bases or of any places where grass seed could accumulate, were then used as seed. The practice was a bad one in as much as it was responsible for sowing grassland weeds, and an undue proportion of the seeds of those grasses which happened to be ripe and unshed when the hay crop was taken. But it did ensure the sowing of suitable local strains which could be counted upon to establish themselves with reasonable certainty and produce precisely the type of herbage the soil would naturally carry. Its defects can be avoided by the simple expedient of collecting a supply of seeds from near-by meadows or a portion of a pasture set aside specially for seed production. Large bunches of the ripened inflorescences of the more important species can easily be gathered by, for instance, the children of a village school. The bunches should then be hung in an airy place to dry off, and the seed knocked out and stored at the first opportunity. The weight of seeds obtained may not be great, especially if attention has been concentrated on the collection of the finer species such as the fescues and meadow grasses. But an ounce of rough-stalked meadow grass will contain some 150,000 seeds, and if this could be sown uniformly over an acre it would provide three or four plants on every square foot. This "acclimatized" seed should be mixed with the purchased bulk for sowing.

Sowing Down to Grass.—The sowing of the complex seeds-mixtures used in the formation of temporary or permanent grassland requires more care and attention to details than the sowing of the seed of any other farm crop. Conditions of soil and weather which would result in a full plant of wheat or swedes may often prove unsuitable for establishing a mixed plant of clovers and grasses.

Failures occur frequently through the action of adverse factors which cannot be entirely controlled, and when the costs of cultivation and of the seed-mixtures are taken into consideration they are undoubtedly expensive. But though these factors cannot be eliminated, their ill effects can be largely minimized if due attention is paid to the features peculiar to mixtures of grass seed. Foremost amongst these is the fact that the seeds of many species are far smaller than those of other agricultural plants. They must, therefore, never be sown deeply, for otherwise their reserves of food material may be exhausted before the first shoots can reach the surface and allow the seedlings to become self-supporting. A depth of half an inch is the maximum to which such seeds should be covered. The larger seeds, such as those of the rye grasses, may be buried more deeply, though even with these the soil covering should not exceed an inch. Further, grass seeds as a whole germinate comparatively slowly. An extreme instance of this is provided by the smooth-stalked meadow grass. The seeds of this species germinate so tardily that even under the favourable conditions provided in seed-testing stations a period of six weeks is considered to be necessary for the completion of a germination test. When sown near the surface, grass seeds are thus exposed for a longer period than most agricultural seeds to the risks of having an insufficient water supply to ensure germination, and then, on germination occurring, of the seedlings drying out before their roots can penetrate to depths where a lasting supply of moisture is available. The risks are obviously greatest in the driest parts of the country, and it is generally recognized that it is in these that the establishment of a grass plant is most difficult. Another, though perhaps less important feature, is that grass seedlings develop slowly, and, consequently, in the earlier stages of growth they are ill fitted to endure the competition of rapidly growing annuals such as charlock and poppies.

The only method of overcoming all of these difficulties is to provide a clean, well worked, compact seed-bed with a surface of two or three inches of finely crumbled soil. This can be most easily obtained after a root crop. If the sowing has to follow a cereal crop the recently shed seeds of annual weeds should, as far as possible, be forced to germinate by stirring the surface soil well before ploughing. Then, in the spring, the weathered furrow slices should be worked down to secure a fine, deep tilth, and during the latter stages of the process a dressing of 10 cwt. per acre of basic slag, or its equivalent in rock phosphates, should be incorporated. In an exceptionally dry spring these operations may result in a considerable though unavoidable loss of moisture. The seed should be sown either by broadcasting or with a seed barrow as soon as the soil surface is in a fit condition. In order to secure a uniform distribution part of the seed is usually sown in one direction and the other part at right angles to it. For this purpose it is a common practice to sow and cover the larger seeds, such as those

of the rye grasses, cocksfoot and clover, first, following on with the smaller seeds, which require to be kept still nearer to the surface. The second sowing should be lightly covered with chain harrows, followed by a smooth roller. The subsequent operations are determined partly by the nature of the soil but mainly by the probable weather for the month or so following sowing. If there is a high water-table or a reasonable prospect of the soil being kept continuously moist for a long enough period to ensure germination, nothing further need be done. But in districts where a dry spell is not unusual in the spring months, the uncertainty of an ample rainfall should be replaced by the certainty of securing a sufficient supply of moisture from the subsoil by repeatedly rolling the surface. The loose tilth must be packed down until the soil is close enough to ensure a steady lift of capillary moisture. There is then little likelihood of the seeds failing to germinate satisfactorily.

Experience has shown that the establishment of a full plant of grass is best effected when the earlier stages of growth take place in partial shade. In some districts cereals are used as a "nurse-crop," either oats or barley being drilled in prior to sowing the seeds of the grasses. This practice involves some risk for in dry weather the corn crop may make excessive demands on the supply of soil moisture, and in wet weather it may become lodged and smother the young grass. If a cereal crop cannot be dispensed with it should be drilled at an under-average seed rate and stiff-strawed varieties should be chosen for the purpose. Victory and Record are suitable oats and Archer or Spratt Archer suitable varieties of barley. It is generally a better practice, however, to grow a crop solely for shading the soil and the young grass. Any light cereal crop or a mixture of one half bushel of barley and a bushel of vetches or peas per acre may be used. The crop should be cut as soon as the ears begin to become clear of the sheaths and made into hay or ensilage. A sowing of rape seed, at the rate of two to six pounds per acre, is occasionally used as a nurse crop and fed off by sheep as soon as the young seeds begin to grow strongly.

Though grass seeds are usually sown in the spring months, autumn sowing produces satisfactory results. It is occasionally carried out in districts with a low spring rainfall, the sowing being made on land subjected to thorough cultivation after a bastard fallow. At this time of the year a nurse crop is unnecessary.

If the growth of weeds is excessive, steps must be taken to check them. The annual weeds are of minor importance unless they are present in such quantities that they form a dense shade. A single cutting will usually be sufficient to exterminate them. The perennials, such as thistles and docks, which can hold their own in competition with the grasses, are more serious. They should be removed once for all by hand pulling. The operation is not difficult for the roots of the docks and portions of the rhizomes of

the thistle broken off during the preliminary cultivations are readily extracted from the loose soil before a dense mat of grass roots has developed.

If the season has been favourable there will be a considerable amount of herbage produced in the autumn. Stock can then be turned in to graze it lightly if the soil is not too wet to be injured by treading. In the following season the field should be cut for hay, preferably as soon as the grass species come into flower. Its subsequent treatment will depend upon whether it is to be used as a meadow or a pasture. In the latter case further mowing will be unnecessary, and from now onwards grazing operations have to be directed towards the formation of a close, uniform weedless sward. Its production depends largely on the manner in which the field is stocked. The earlier grazing should be effected by sheep and cattle.

The former graze somewhat closely defoliating the bottom grasses and showing a tendency to neglect the coarser species. The latter graze less selectively, so that a combination of the two results in a uniform biting down of the herbage. Horses are unsuitable for grazing a young pasture, for they bite portions down bare and leave their droppings on others. A steady deterioration then begins unless the resulting coarse, over-manured patches are either grazed by cattle or the top grass is mown in July or early August. Both over- and under-stocking are deleterious. The former leads to the development of weeds, especially of those with a rosette-like habit of growth, such as plantains, cat's ear and daisies, whilst the latter may result in the partial disappearance of white clover. The aim of the grazier should be to secure a succession of flushes of young grass for consumption at the stage of their maximum feeding value. Each flush should be grazed down when the foliage is some three or four inches high, and the field then left to develop a fresh one. If sufficient stock for the purpose is not available, the excess of herbage should be removed with a mowing machine to prevent the development of coarse tufts of cocksfoot and Yorkshire fog and of such weeds as hard heads (*Centaurea nigra*).

By the end of the third season fields laid down to permanent grass often reach a critical stage in their development. Owing largely to the lack of permanence of the red clover, the bulk of the herbage falls off considerably, and as the growth of the finer bottom grasses may not have proceeded far enough to knit the coarser species into a compact turf, patches of bare soil become visible. This partial failure is especially common on clay soils where the gradual disappearance of the initial tilth has resulted in indifferent drainage and inadequate aeration. The problem then has to be faced as to whether it is worth while to continue the attempt to make a good lasting turf or to break up the land again with the object of putting it down to a long ley. Local knowledge is the best guide. If the turf on fields of long standing is satisfactory, an attempt at improving the field will probably be worth making. If

it is not the choice between a productive ley and bad or indifferent permanent grassland is not difficult.

Unfortunately little can be done to improve the physical conditions of the soil. But the surface can be torn up with spike harrows with good effects on the soil ventilation, and in the resulting partial tilth a light seeding of six or eight pounds of perennial rye grass can be made and covered in by treading with sheep or by rolling. A further dressing of a phosphatic manure is usually particularly beneficial at this stage, for the white clover is stimulated into further growth and the bare patches are consequently covered and better conditions of nutrition provided for the grasses.

Temporary Grassland.—By putting land down to grass for a short period, not only are some of the major difficulties of establishing permanent grass avoided, but certain marked advantages are secured. The greater part of the permanent grassland in this country, even when reasonably well managed, does not produce the quantity of vegetation it is capable of growing. Periodical cultivation and manuring are essential for the maximum growth of all plants. Where economic reasons make these operations too costly to carry out at short intervals, they can be replaced by cultivating at longer intervals with advantageous results. Grass is an ideal crop for this purpose. The laying down of land to grass for a four or five year period ensures, in the first place, a considerable saving of labour. Then, when productivity falls off and the critical stage in the development of grassland has set it, the turf can be ploughed under. The immediate result is that the decay of the herbage and the roots of the grasses and clovers produces a humus-containing tilth such as no other method of cultivation can give. This can be utilized for the growth of other crops, so that the grass crop then takes its place in the rotation. Alternatively the land can again be sown with a mixture of grass seeds and so kept, if necessary, permanently under temporary grass. Such a procedure leads to the steady improvement of the land by nature's own method of soil formation. The one drawback to it is the periodical expenditure which it entails for cultivation and seeds. Against this a number of immediate advantages have to be set. Foremost amongst these is the fact that temporary leys used either as meadows or pastures are far more productive than average permanent grass, for they may be expected to yield at least half as much again. Next, especially in the case of the shorter leys, large quantities of highly nutritious leguminous herbage can be grown. The grass flora, too, is more subject to control, and less consideration need be paid to the permanence of various species and to the flora of the locality, with the result that profitable use can be made of such short-lived species as tall oat grass. Where circumstances demand it, larger quantities of the earlier growing species can be included in the seed-mixtures. Temporary grass, too, has the great advantage, especially in the drier parts of the country, that it is far more resistant tc the effects

of drought than permanent grass. Some traces of the initial tilth persist even after four years, with the result that the roots range more deeply and the loss of water by evaporation from the surface is also less.

In deciding upon the constitution of the mixtures to be sown for the production of temporary leys, the following points have to be taken into consideration. Those for leys which are to remain down for two seasons or, at the most, for three, should obviously consist only of clovers and those species of grasses which reach their maximum yielding capacity in a short period. Further, their permanence is a matter of no importance. For the longer leys which are required to last for four seasons, though they may, if still sufficiently productive, be left down for a still longer period, the choice of species is less limited. In fact mixtures similar to those suggested for sowing down land permanently (p. 291) are occasionally employed. But the inclusion of the slow-growing bottom grasses is not essential, and a reasonably close, weed-excluding sward will be formed by the white clover. The omission of these seeds lessens the cost of the mixtures, and a further saving can be effected by reducing the quantities of white clover seed, though this should not be done drastically on account of the manurial value of a sward of this nitrogen accumulating plant.

The shortest leys, usually sown with the object of providing a crop of hay and some autumn grazing, are often little more than clover crops, and they are liable to the same drawback, namely, that they may partially fail owing to attacks of either eelworm or *Sclerotinia trifoliorum* (p. 379). The mixtures in general use are composed of the seeds of either broad red or late flowering red clover and Italian or perennial rye grass. The proportion of clover to grass varies widely. A generally used mixture, based on the results of a number of experiments at Cockle Park, consists of 18 lb. of perennial rye grass and five of late flowering red clover per acre. But the proportion of clover is often largely increased, and mixtures such as six pounds of perennial or Italian rye grass and 15 lb. of broad red or late flowering red clover are made use of. Further investigation is necessary before any very definite decisions can be made as to which is generally the most useful of the two clovers and the two rye grasses. The evidence, at present, points to mixtures of late flowering red and perennial rye grass producing heavier crops than those of broad red clover and Italian rye grass. They also appear to be more effective in the control of weeds. Against this may be set the fact that Italian rye grass will provide earlier keep when this is required than perennial. Where clover sickness is to be feared the mixture may be re-inforced by the addition of alsike and trefoil :—

Perennial rye grass	18 lb. per acre.
Late flowering red clover	5 ,,
Alsike	1 ,,
Trefoil	1 ,,

For leys which are to occupy the land for an additional season, a wider choice of grass species is available, but the use of broad red clover is ruled out by its biennial habit of growth and its place should be taken by a mixture of the late flowering variety and wild white clover. Cocksfoot, Timothy grass, tall oat grass and meadow fescue may be made use of in addition to perennial rye grass. But seeds of the moisture-loving Timothy should not be included in mixtures for sowing in districts where there is not an ample rainfall, and meadow fescue should only be sown in situations in which it is known to thrive. A mixture which is rapidly becoming a standard one is as follows :—

Perennial rye grass	16 lb. per acre.
Cocksfoot	10 ,,
Timothy	4 ,,
Late flowering red clover	4 ,,
Wild white clover	1½ ,,

This is again based on the results of investigations carried out at Cockle Park, where it has produced crops of about two tons per acre throughout the three-year period. Its constitution may be modified as circumstances suggest, and one addition, namely, one pound per acre of trefoil, has proved useful both on clay and sharply drained calcareous soils. Though only of annual duration, it functions as a long-lived plant by seeding down freely. The replacement of four pounds of the cocksfoot seed by one pound of crested dog's-tail and of rough-stalked meadow grass leads to the production of a closer sward and gives a mixture suitable for producing a hay crop, followed by grazing for the remainder of the period. There is also the possibility of its standing well into the fourth season, or even of becoming the basis for still more permanent grass.

Effects of Manures on Grassland.—The results of applying artificial manures to permanent grassland have been under investigation at Rothamsted for three-quarters of a century. A field was set aside for this purpose in 1856, and on the twenty or so plots into which it was divided, all except two, reserved as controls, have received the same experimental dressings annually. For over half-a-century the field has been treated entirely as a meadow, the aftermath being cut for hay instead of being grazed as it was in the earlier years. Each year the yields of the various plots have been determined and the herbage sorted into three groups, grasses, clovers and weeds, whilst at intervals of five years a complete botanical analysis has been made. A great volume of information has consequently been obtained. Unfortunately it is unique, for no similar experiments have been made elsewhere. Hence no detailed comparisons of the effects of the long continued application of artificial manures under conditions different from those at Rothamsted are possible. There have, however, been large numbers of manurial trials carried out all over the country and the results of these, where available, generally confirm those of Rothamsted in a

striking fashion though their scope is narrower and their duration far less.

The first effect of applying any dressing capable of acting as a plant food material to grassland is to upset the equilibrium arrived at between the species composing its flora. Even if the rate of growth only is affected some grow more vigorously than others, with the result that they tend to crowd out others from the beginning. The result of continuously applying an artificial manure may then be expected to be a radical change in the constitution of the herbage. Such changes are extraordinarily clearly marked on the Rothamsted plots. Each artificial manure and each combination of them has given rise to a more or less distinctive flora, and in doing so so altered the character of the turf that it is no exaggeration to say that certain of the plots could be picked out on walking blindfold across the field. The length of time the experiments have been in progress has, no doubt, been chiefly responsible for the clarity of the results. But the system of management by which the grasses have always been allowed to grow to the maximum, so permitting the factors associated with crowding and shading to exert their full influence, cannot have been without effect. It would serve no useful purpose here to attempt to follow out the effects of the various manures on the individual grasses, clovers and weeds. Their general effects on the herbage as a whole are, however, of outstanding agricultural interest.

The first result of applying any nitrogenous manure to grassland is a great increase in the growth of the foliage and stems. The new growth is characteristically dark green in colour and distinctly more succulent than that of the plants grown without an additional nitrogenous supply. It also becomes especially liable to the attacks of such parasitic fungi as the rusts, and should the crop become lodged the heavily shaded portions tend to decay rapidly. Both of the two commonly used nitrogenous manures, sulphate of ammonia and nitrate of soda, have this stimulating action, and their value for increasing the yield of hay is well known. The application of one hundredweight per acre of sulphate of ammonia may be expected to result in an increased yield of from 6 to 10 cwt. if the weather conditions are favourable, whilst nitrate of soda is still more effective. These two manures have very different effects on the herbage when they are used for several seasons in succession. Both eliminate the clovers and leguminous plants generally, sulphate of ammonia acting in this respect far more rapidly than nitrate of soda. This differential action is frequently made use of for the extermination of clovers on lawns and golf greens, on which such plants are looked upon as undesirable weeds. Concurrently where the former manure is used, creeping bent and the fine fescues increase in quantity, whilst the latter encourages the growth of meadow foxtail and downy oat grass (*Avena pubescens*). The repeated application of sulphate of ammonia results, as is well known, in the development of an acid soil. At Rothamsted the plots so

treated carry a typical sour soil vegetation, the grass flora being represented mainly by creeping bent and fine fescue, which account for approximately 30 and 55 per cent. of the herbage and the weeds by sheep's sorrel, whilst the clovers, unable to root down in the superficial layer of peaty material which has been formed, have completely disappeared. This type of manuring, which ultimately results in the ruin of agricultural grassland, is now being repeated wholesale on golf-greens with the object of producing an agrostis-festuca association.

Four of the Rothamsted plots are used to test the effects of these two nitrogenous manures in association with mineral manures, the dressings given being 400 or 600 lb. of ammonium salts, or 275 or 550 lb. of nitrate of soda, with 3·5 cwt. of superphosphate, 500 lb. of sulphate of potash, 100 lb. of sulphate of soda and 100 lb. of sulphate of magnesia. Such dressings are far larger than those made use of in ordinary agricultural practice. The result of their use has been the production of over-average crops. The plots receiving 400 and 600 lb. of ammonium salts per acre have averaged 54 and 65 cwt. of hay over the whole period, and those receiving 275 and 550 lb. of nitrate of soda 48 and 59 cwt. respectively. Where ammonium salts have formed the source of nitrogen the leguminous plants have disappeared completely, and most of the weeds have been crowded out. The heavier dressing has also eliminated many of the grass species, with the result that the herbage now consists almost entirely of Yorkshire fog, tall oat grass and foxtail. A less drastic simplification of the flora has followed the application of the lighter dressing. Tall oat grass, sweet vernal, smooth-stalked meadow grass and sheep's fescue form the dominant species, and foxtail, cocksfoot, Yorkshire fog and creeping bent still contribute appreciably to the herbage. As compared with the flora of the plots receiving sulphate of ammonia only, it is rich in species. Nitrate of soda has not suppressed the leguminous plants so completely, and small quantities of white clover are still to be found even on the more heavily supplied plot. The meadow vetchling (*Lathyrus pratensis*) also survives in fair quantity. Neither is the number of grass species so reduced, though characteristic changes in their frequency have occurred. The most striking of these is a great increase in the quantity of soft brome grass which now accounts for nearly a quarter of the weight of the herbage though it is only present in traces on the other plots. Foxtail, tall oat grass and smooth-stalked meadow grass have become the dominant grass species, whilst beaked parsley (*Anthriscus sylvestris*), which only occurs rarely on the other plots, grows in great abundance.

The only phosphatic manure available when the Rothamsted plots were laid out was superphosphate of lime. This has been applied continuously to one plot at the rate of three and a half hundredweight per acre. The plot is now little better than the impoverished un-manured controls. On it weeds such as hawkbit (*Leontodon hispidus*), burnet (*Poterium sanguisorba*) and ribwort

(*Plantago lanceolata*) are abundant, and the commonest grass is quaking grass (*Briza media*).

Now, in addition to the superphosphate of lime there are other cheap sources of phosphates such as basic slag, various ground mineral phosphates, bone meal, steamed bone flour, etc. Numerous trials with these have established the fact that with comparatively rare exceptions the result of their application is an abundant growth of all leguminous plants, and especially of white clover. Fields so treated, on which only traces of the plant can be found after careful searching, may become an almost continuous white clover mat after a single dressing. No complete explanation of this extraordinary development is available yet, but it is generally assumed that it is in some way connected with the fact that the growth of leguminous plants is dependent on the bacterium-containing nodules which are so distinctive a feature of their root-systems (p. 401). For the time being all that can be said is that clovers "respond" to phosphatic manures. In doing so they accumulate nitrogenous materials which in time find their way into the soil and become available as food material for the grasses. A dressing of a phosphatic manure is thus an indirect form of nitrogenous manuring.

The Rothamsted plots provide relatively little information regarding the effects of potash on the flora of grassland. One pair of plots is available for comparison. These have been treated with ammonium salts plus, in one case, a complete mineral dressing, and in the other a similar mineral dressing minus sulphate of potash. The lack of potash results in a well marked decline in the yield of hay and a retardation of the flowering period of the grasses. Most of the recent experiments indicate that potash alone, when used for comparatively short periods, has little effect on the herbage. Probably the potash requirements of the constituents of the grassland flora are amply met by the supply available in the soil, except in the case of those of an extremely sandy or gravelly nature.

Although the grassland flora of soils overlying both chalk and limestone is usually rich in species the grasses, as a whole, are not calcareous plants and most of those of agricultural value thrive on soils with a low or negligible calcium content. Acid soils, however, are distinctly prejudicial to their growth, and very few species contrive to exist on really sour soils. No uniformity of results can therefore be expected to follow the liming of grassland. Accumulated experience has now shown that over a great part of it the application is a mere waste of money, whilst on the other hand, it is the only method of improving the vegetation of sour soils. It is usually easy to determine whether liming is likely to be beneficial. If the flora consists largely of bent grasses, sheep's fescue and Yorkshire fog, if white clover is only present at the most in traces, and tormentil (*Potentilla Tormentilla*) and heath bedstraw (*Galium saxatile*) are the commonest weeds, then the soil is definitely sour and the application of lime in some form is desirable.

Soils carrying a scanty vegetation of this type often show considerable patches of bare earth. If a turf is lifted from them the edges show sections of a skin of peat-like material consisting of the undecomposed remains of previous years' growth. This tends to increase in thickness year by year, for the processes of decay go on slowly under sour soil conditions. It forms an unfavourable stratum for the runners of white clover to root into, and the plants fail to spread, even if they do not disappear entirely. Rain water falling on the surface is retained by the peat, with the result that after a dry season the soil below it may be dry for weeks after rain has fallen.

When heavily limed the peat mat gradually disintegrates, the process often going on so slowly that no effects are visible for two or three years. As it disappears the clovers re-establish themselves and the grazing improves considerably. But no pronounced changes occur in the flora, and the bent grasses still predominate. Fields showing such features are common on the millstone grit and on carboniferous formations. They may also occur on boulder clay in districts of high rainfall. Where they are found in the neighbourhood of large, smoke-ridden, manufacturing centres they represent some of the most unproductive grassland to be found in the country.

The presence on neighbouring arable land of such weeds as corn marigold (*Chrysanthemum segetum*), spurrey (*Spergula arvensis*) and sheep's sorrel (*Rumex Acetosella*) is an indication of some degree of soil sourness. If the acidity is not pronounced its effects on the grass flora are not obvious. Liming may then result in some improvement or its effects may be negligible. Such soils sour rapidly when dressings of sulphate of ammonia are used on them. They can then be quickly brought back to their original condition by the application of lime.

The occurrence of such plants as rest-harrow (*Ononis arvensis*), wild clematis (*Clematis vitalba*), dog rose and hawthorn is an indication that the lime contents of the soil are ample for the agricultural grasses. The vegetation on soils derived from chalk and limestone, or on boulder clay, Oxford clay or the lias clays is rarely benefited by the application of lime. But exceptions may be met with where a heavy rainfall has leached the surface soil, or again, where the use of continuous dressings of ammonium sulphate has decalcified it.

In order to secure the best results from permanent grassland it is essential to keep up its fertility. As time goes on it deteriorates owing to the removal of food materials from the soil, either in the form of hay or in the carcasses of live stock. The depreciation is so gradual that it is often overlooked. Its chief characteristic is to be found in changes in the grass flora and a markedly increased weediness. The only definite information on the course of these changes is provided by the Rothamsted grassland experiments. The two control plots, which have been mown twice yearly for half a century, have never received any manure. The periodical analyses show no

striking changes in the total weight of the herbage. Its character, however, has altered steadily owing to an increase in the quantity of such weeds as burnet, hawkbit and knapweed, and a decrease in the grasses. The weeds now account for about one-half of the total produce of the two plots, and the grass flora is represented mainly by quaking grass and sheep's fescue. The impoverishment is typical of much of the poor grazing land to be found all over the country.

The judicious use of artificial manures, either alone or in association with farmyard manure, will do much to prevent this subtle deterioration. The numerous demonstrations carried out at experimental stations all over the country have provided a great deal of information on the best methods of employing them, and the general decrease in their prices has enabled farmers to take advantage of the knowledge which has been obtained. But so great are the differences in grassland floras, in soils and climate, as well as in the requirements of individual farmers, that it is impossible to do more than give general indications on the best manures to be used for any particular purpose and on the best times for applying them. But much valuable local information can generally be obtained from the nearest County Council Agricultural Organizer.

Manuring Meadows.—On dairy farms and farms on which the whole supply of yard manure is not required for the arable land, the yields of hay are kept up by dressings of farmyard manure varying from 10 to 20 tons per acre. Where this practice is continued year by year the tendency is towards the production of bulky and somewhat coarse herbage which is often rich in the undesirable Yorkshire fog and singularly deficient in clovers.

Where farmyard manure is not available nitrogenous manures are essential for the continuous production of heavy crops of hay. If their use is suspended, especially on fields which have been systematically mown, the yields fall off immediately. The nitrogenous manure most generally used for the purpose nowadays is sulphate of ammonia. This is applied in March or early in April at the rate of one to one and a half hundredweights per acre in the expectation, if the weather conditions are favourable, of securing an increase in the hay crop of from half to three-quarters of a ton. But equivalent dressings of nitrate of soda or nitrate of lime may be used instead, and this substitution has the advantage, particularly on soils with a low lime content, that souring of the land is less likely to follow. As the Rothamsted results have shown (p. 299), the continuous use of nitrogenous manures alone is inadvisable, as it leads to a certain deterioration of the herbage. They should be supplemented with phosphatic manures and, at longer intervals, in many cases with lime. The phosphatic manures have never been used on meadow land to the same extent to which they are used for the improvement of pastures chiefly because the clovers, though valuable when present in quantity, do not generally constitute a large proportion of the mixed herbage present in hay. If applied to meadows

they may or they may not produce an increase in the crop. If the yield is already in excess of a ton to the acre they will, as a rule, have little effect on the quantity, though the quality may be markedly improved. On the other hand, where the yields are low and of the order of 10—15 cwt. per acre, a dressing will often increase the crop to 20 or 25 cwt. In both cases there is the likelihood of an improvement in the quality of the aftermath.

The results are most marked on the heavy clay soils, often described as "slag-land," and on soils which are not deficient in lime.

Either basic slag, ground mineral phosphates or superphosphate of lime may be used for the purpose (p. 305).

Where either farmyard manure or a nitrogenous artificial manure has been used for some years, an application of lime may have decidedly beneficial results, even though the flora shows none of the characteristics associated with sour soils. Frequent dressings are rarely needed for the effects are very persistent.

A definite manurial rotation such as farmyard manure in the first year, a phosphatic manure in the second, and a nitrogenous manure in the third, with an application of lime at intervals of, say, seven years, would probably do much towards keeping up the quality of the herbage as well as producing heavy crops of hay.

Manuring Pastures.—It is now generally recognized that, with some few exceptions, the outstanding method of improving grazing land is to apply occasional but liberal dressings of a phosphatic manure. Experiments in all parts of the country have shown that this simple procedure will often double the stock-carrying capacity of the land. Moreover, it costs little and the effect, unlike that of using a nitrogenous manure, is a lasting one. Whilst any phosphatic manure will answer the purpose, basic slag has always been used on a far larger scale than any other. This material is a bye-product of the Bessemer process for making steel. Within recent years, however, this has been superseded by the open hearth process, with the result that different types of slag are now being produced. Their agricultural value is now the subject of numerous investigations. One kind, resulting from a process in which no fluor-spar is used, contains from 10 to 17 per cent. of phosphoric acid, and, treated with a two per cent. solution of citric acid, it shows a solubility of 80 per cent. This may be used in place of the original basic slag, which is now only obtainable on the Continent. The fluor-spar basic slag, with a phosphoric acid content of 12 to 15 per cent., is only 40 per cent. soluble. It is thus a slow acting and less valuable kind.

The relatively low price per unit of phosphoric acid in ground mineral phosphates, together with the uncertainty of the values of the newer kinds of basic slag, has led to many investigations on the possibility of substituting the former for the latter as manures for grassland. Their value has been found to depend very largely on the fineness of their grinding. Material treated so that 80 or 90 per cent. of it will pass through a sieve with a mesh of 120 to the

inch has given very satisfactory results, especially in districts with a high rainfall. A number of these mineral or rock phosphates are now available. They differ considerably in their phosphoric acid content and solubility. Perhaps the most generally satisfactory is the North African sort known as Gafsa. This, as far as experimental work goes at present, appears to give better results than either the Florida or the Nauru rock phosphates although its phosphoric acid content is lower. If applied at the rate of five or six hundredweight per acre the results are comparable with those obtained from dressings of 10 cwt. of basic slag, and further, the cost is considerably less.

In some of the Dominions and in the United States superphosphate of lime takes the place of basic slag in this country. In spite of its greater cost it still finds a somewhat limited use for the improvement of pastures here. It is especially valuable in dry districts and on soils overlying chalk and limestone.

To secure the best results from phosphatic manuring heavy dressings should be used. As a general guide 10 cwt. per acre of basic slag, or its equivalent in some other form, is the quantity likely to prove most profitable on fields which are being treated for the first time. It should, moreover, be put on in a single dressing, for in a five-year period this quantity will give a better return than five two-hundredweight dressings applied annually. The manure may be applied to the pastures at any season of the year, for little is lost by leaching. It should not, however, be put on during wet weather with the object of getting it washed into the soil as quickly as possible, for it is apt to set when in contact with a moist surface. Even under the driest conditions these heavy dressings of basic slag or of mineral phosphates are not harmful to the vegetation, but superphosphate of lime may cause an appreciable scorching of the foliage. The effect is only transitory, and the plants soon grow again normally. It can be avoided, however, by dividing the bulk of the manure into two or three parts and applying them at short intervals.

The soils which particularly repay the cost of phosphatic manuring are the heavy clays and loams and the calcareous soils of chalk and limestone districts. But extraordinary as its effects generally are, it will fail to effect any improvement of the herbage if some essential food material should be lacking in the soil. In cases where phosphatic manures have proved to be useless investigation has often shown that the lack of potash or of lime has been the cause, and once these deficiencies have been remedied, the usual results of its application follow. Thus the light, sharply drained soils of sandy or gravelly districts are frequently unresponsive to phosphatic manuring alone, but if it is supplemented with a potash containing manure, such as kainit, an improved type of flora is soon obtained. Similarly, the failures on excessively sour soils are due to the lack of lime, and it is useless to expect any marked improvement from their use until the mat of dead vegetation has

been broken down and conditions suitable for the spread of white clover established (p. 302). The inadequate drainage which is so often to be found on heavy soils may also prevent phosphatic manures producing their expected results. Its effects are often visible on the "high-backed" clay lands where, not uncommonly, a vigorous growth of white clover is found on the ridges, whilst in the valleys the flora remains unaltered. Where the systematic improvement of pastures on such land is being undertaken, advantage can often be taken of the fact that it is frequently suitable for mole-draining.

Hitherto nitrogenous manures have not been used so extensively for increasing the production of pastures as for meadows. An increase in the bulk of the crop in June makes little appeal to graziers, who frequently find that at the height of the growing season there is more herbage than the stock can consume, whilst both before and after the supply may be inadequate. The possibilities of spreading the supply over a longer period and at the same time of making use of it when in its most nutritive condition by taking advantage of the growth-forcing properties of nitrogenous manures are now being investigated. The system in use at present requires a number of small fields of approximately the same size, or a large field fenced off into a series of small units. On each of these, in turn, a crop of young grass is forced by the application of a nitrogenous manure, generally sulphate of ammonia, used at the normal rate of one hundredweight to the acre. The first dressing is given early in February with the object of producing not only a heavier crop but an earlier crop than usual. When the foliage has reached its maximum nutritive value, that is when the grass is some three or four inches in height, it is closely grazed. The stock are then transferred to a second field or section, thence to a third and so on, on all of which similar crops have been forced. As soon as each has been grazed another dressing of sulphate of ammonia is given in order to keep up the rapid production of a heavy crop of high-protein grass. In the aggregate, some three to four hundredweight per acre may be applied in a single grazing season.

The system has the advantage that the grazing period is prolonged, for crops can be secured both earlier and later than normal, and further, that the grazing itself is under better control owing to the uniformity of the crop and the small areas which have to be defoliated. But this intensive method of management has difficulties of its own. The yield of herbage is very largely dependent upon weather conditions: in dry seasons the manuring will have little effect, and in wet so much grass may be produced that the available stock cannot cope with it. The surplus must then be removed either for hay or ensilage. A small area treated in this manner may form a useful adjunct to a grassland farm, but it should be backed by a larger area of less intensively managed land, either to carry a temporary surplus of live stock or to be mown as circumstances dictate. Where sulphate of ammonia is used continuously

on this scale it is almost certain that the clovers will disappear and the land will quickly become sour. The former can be prevented by the use of phosphatic manures and the latter by liming at intervals which will depend largely on the initial lime content of the soil.

Various forms of lime are available for the purpose, and as their effects are much the same, in the long run if not immediately, a consideration of their relative costs may determine which should be used. Two of the most satisfactory forms are provided by finely ground limestone or chalk. Either may be applied, at the rate of two tons per acre, by means of a distributor or by broadcasting with shovels from a cart. If the material becomes wet it does not set but forms a paste which again falls into a powder on drying. It can consequently be well distributed by harrowing. These materials have the advantage that they can be applied at any convenient time for neither has any injurious effect on herbage or on live stock. Moreover, they can be purchased at any time, for they undergo no deterioration on storage.

Quick lime has the advantage over ground limestone and ground chalk that smaller quantities can be used on account of its higher calcium content. A possible saving in transport costs may therefore be set against the fact that it is a less convenient material to apply to the land. It is usually purchased in the form of lump lime.

Quick lime must be applied during the late autumn or winter when the herbage is in its most dormant condition. The lumps should be placed in small heaps in the field and allowed to slake. The resulting material must then be distributed as uniformly as possible by means of shovels and harrowed in immediately. A dry period is necessary for this operation, for the slaked lime, when wetted, cakes into hard lumps. Slaked, or hydrated lime may also be purchased in the form of a fine powder which can be spread uniformly by means of a distributor, but it is unpleasant to handle and, as a rule, costly compared with quick lime.

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CHAPTER XIV.

ENSILAGE AND HAYMAKING

The practice of ensilage enables a green crop to be conserved in the succulent condition for feeding to farm animals during winter. There is evidence that the ancients were in the habit of storing grain in pits in the ground, and little doubt can be entertained that ensilage in its modern form can trace its origin to this primitive practice. The process of ensiling green fodders, however, is of much more recent origin and was first practised in Central Europe. It was not until the second half of the last century that this new method of fodder conservation attracted much attention in this country. In the year 1885, following a series of trials of the method, Mr. George Fry published a short treatise embodying the results of his experiences. It is of interest to note that his conclusion respecting the essential condition for the production of sweet silage, namely, the attainment in the silo of a temperature of at least 50° C., has been borne out by the results of more recent investigations into this and kindred questions.

It was in the United States of America, however, that the practice of ensilage gained the firmest foothold. Here, for the first time, the process was carried out in tall cylindrical towers, a modification of the practice which greatly reduced the wastage during storage of the green crop. The spread of ensilage in the United States was further encouraged by the favourable conditions in that region for the growth of maize, which is the silage crop *par excellence.* The practice is now so widespread, that it is computed that there are now almost a million silos in use in the northern half of the American continent. Early in the present century, the cylindrical stave silo was introduced into this country, where it soon gained the favourable interest of agriculturists in many counties. Generally speaking, however, the importance of ensilage in farm husbandry has not so far received from British farmers the recognition to which it is entitled.

Crops Suitable for Ensilage.—Amos states that an ideal crop for ensilage should satisfy the following conditions :—(1) It should be easy and cheap to grow, so that its cultivation does not interfere with that of other more important crops. If seeding and harvest occur when other crops do not require attention, so much the better. (2) It should be a reliable crop, not subject to great variations in yield, so that the farmer can calculate with reasonable certainty his supply of winter fodder (the disadvantage of the root crop in some districts is its uncertain yield). (3) It should be easy to harvest, capable of being cut with the grass cutter, easily carted and quickly chaffed for filling into the silo. (4) It should be capable of reaching with absolute certainty the required degree of maturity for ensiling, since immature crops are apt to give rise to sour silage. (5) The silage produced should have a relatively

high feeding value, should be digestible and contain a reasonable amount of protein. (6) The growing of the crop should provide time for weed destruction either before sowing or after harvesting, or should facilitate suppression of weeds by smothering.

It may be stated generally that most of the usual forage crops are suitable for conversion into silage with the exception of members of the cabbage tribe (Brassicæ), the latter being too succulent and liable to give rise to a foul-smelling product. Ensilage of meadow-grass, when conditions are unfavourable to hay-making, offers obvious advantages. Grass cut late in autumn can be converted into good silage when the prospects of turning it into hay may be remote. The second and third cuts of mixed grasses and clovers grown on arable land are frequently filled into the silo, the first cut being converted into hay. Attention may also be directed to the fact that encouraging results are being obtained in the ensilage of grass in its young stages of growth, the material thus being conserved at its phase of maximum feeding value for use during winter.

It should be noted that leguminous crops are not suitable for ensiling alone, the resulting product frequently having a strong, unpleasant odour. In admixture with grasses or green cereals, however, the leguminous fodder crops are very suitable. Lucerne sown with cocksfoot or rye-grass, for example, has given highly satisfactory results on suitable soils.

In those parts of the world which favour its growth, maize is pre-eminently the best crop for silage. Not only does it produce a very heavy crop of succulent and digestible forage, but by reason of its stout, erect growth, it can be cut and loaded very readily as well as rapidly fed and chaffed in the cutter. These factors render it cheap to grow and economical to handle per food unit. In this country, however, attempts to produce silage from maize are by no means always successful. The summer climate does not allow either a long enough growing period, or a sufficiently hot one, to bring the crop to the desired stage of maturity for ensiling, at which stage the maize grains should be firm and in a "glazed" condition. Further, the crop is exceedingly sensitive to night frosts in the seedling stage and the foliage is liable, at a later date, to be cut down by early frosts in autumn. Maize (*e.g.* the American Horse Tooth variety) is more frequently grown in this country for green soiling than for ensilage, but it should be emphasized that at least one early-maturing variety, the French Jaune Gros du Domaine, has given excellent results when grown for silage at Cambridge and in the southern counties.

The most uniformly successful silage crops in this country are mixtures of oats and vetches, or oats and peas on light land, and beans, oats and vetches on heavy land. The defect, from the silage standpoint, of the vetch crop when grown alone is its tendency to become laid, but this difficulty is overcome when it is sown along with a supporting crop such as oats, wheat, rye or beans. Amos

recommends the use of Grey Winter oats, which besides possessing the requisite degree of winter hardiness, are able to develop rapidly in the spring. He gives the following rates of seeding per acre for autumn sowing: on light land, 6 to 8 pecks of vetches with 8 to 10 pecks of oats; on heavy land, 3 to 5 pecks of vetches with 8 pecks of winter beans and 4 to 6 pecks of oats.

The sunflower is often grown for silage in certain parts of the world which are too cold for maize (*e.g.*, the Pacific North-west). It is a hardy plant capable of withstanding drought and frost. The process of seeding is relatively cheap and it displays free, rapid growth on poor light soils, yielding a heavy tonnage of green matter per acre. The crop has not been widely tested in this country, but trials at Cambridge have indicated that the silage produced from this crop is rather fibrous and indigestible and of distinctly lower feeding value than maize silage. It may be that different methods of cultivation (such as close planting) might lead to a reduction in the fibrous nature of the stems.

Mention should finally be made of the growing practice in this country of ensiling sugar beet tops. These are not generally suitable for filling into tower silos, but may be ensiled in pits or clamps close to the fields on which they have been grown.

The Making of Silage.—Green fodders may be converted into silage by three methods:—(1) in specially constructed buildings called silos, usually erected in the form of tall cylindrical towers; (2) in silage clamps and (3) in silage stacks. It may be stated at once that although ensilage in the clamp and stack is often successfully carried out and affords a useful and cheap method of saving green crops in wet hay-making seasons, yet in those cases where ensilage is to form a definite part of the farm system, there can be no gainsaying the economy and advantages of a properly constructed silo. The erection of a tower silo involves an initial capital outlay, but its use enables silage of good quality to be made with very little waste; on the other hand, although clamps and stacks involve little or no expenditure of capital, the silage obtained by their use is frequently of poor quality and the wastage is always considerable.

The Tower Silo.—Silos are usually constructed of wood or concrete, and less frequently of steel, the tower being 30 ft. or more in height and varying from 12 to 20 ft. in diameter. When filling the silo, which should preferably, although not necessarily, be carried out in fine weather, the green crop is chaffed and blown to the top of the silo by means of a silage cutter and blower. Care should be taken to ensure a regular and uniform filling. As each layer of green chaff is spread out, it should be firmly trampled, the centre of the mass being kept slightly higher than the sides. This treatment leads to compact settlement and exclusion of most of the air, conditions which are essential to the production of good silage.

The top layers in the silo should particularly be very firmly compacted, in order to minimize wastage at the exposed surface

as a consequence of mould action. With this object in view, it is sound policy in the final stages to fill in a few tons of moist, succulent material, such as ditch brushings or nettles, since such green stuff settles down very compactly and prevents the penetration of air into the underlying mass. If such material is not available for this purpose, the same object may be achieved by turning the hose-pipe on to the green crop as it passes into the silage cutter during the last stage of filling.

Silage made in towers may, if desired, be fed without danger to farm animals immediately after completing the filling of the silo. On the other hand, it may be stored in the silo for a period of two or three years without deterioration in quality, provided the conditions are such as to prevent access of air.

THE CLAMP SILO.—When choosing the site for a silage clamp, care should be taken that the ground in the vicinity is not subject to water-logging during winter and that the selected site is close to a road for carting purposes. Amos recommends that the floor of the clamp should be rectangular in shape and excavated to a depth of from 1 to 3 ft., the soil being thrown to the sides. A convenient width is from 12 to 16 ft.; the length, however, depends on the weight of crop to be ensiled. It is not usual to chaff the green crop for purposes of clamp ensilage, but merely to draw each load over the clamp by means of a horse before unloading and spreading. A clamp silo is made in much the same way as a drawn-up clamp of farm-yard manure.

The greatest difficulty in connection with the clamp is to prevent the silage in the bottom layers from being sour. This difficulty may be overcome by filling into the silo in the first stages a portion of the crop which has been allowed to wilt for two days after cutting, such partially dried material not packing so tightly and heating more readily in consequence. Failing this procedure, the filling process should be suspended for two days after a layer of 2 to 3 ft. of material has been spread over the floor of the clamp. The crop heats up considerably during this interval and in the subsequent stages of filling, the heat spreads through the mass of the material and ensures the production of a palatable type of silage. When carting is completed, the top of the clamp should be covered with earth without delay and finally, earth should also be thrown against the sides.

THE STACK SILO.—The essential conditions for successful ensilage in a stack are: (1) a level piece of ground, the stack being built straight off the earthen floor; (2) a sheltered situation and in particular, protection from the prevailing wind, by such devices as sailcloths, for, if allowed free access to the stack, it may cause over-heating on the exposed side and unequal settlement of the ensiled material; (3) careful covering or thatching of the stack to give protection against ingress of rain and the spoiling action of moulds; (4) the cutting of the sides of the stack after completion in such a manner as to leave a straight and compact surface exposed

to the air, thus preventing the action of moulds from penetrating any considerable distance into the stack; (5) the weighting of the stack to assist consolidation of the mass. A simple inexpensive device used at Cambridge for this purpose consists of two long poles placed along each side at the top of the stack, over the poles being passed strong wires weighted at each end by railway sleepers.

The amount of wastage by mould action in the case of stack silage may be very considerable, especially with small stacks, where the exposed surface is large in proportion to the bulk of the ensiled crop. The process is only efficient when very large stacks are made, but when it is resorted to for the purpose of making sweet silage from a hay crop in danger of being ruined by inclement weather, considerations of economy and efficiency become of secondary importance.

Scientific Aspects of Ensilage.—When a green crop is chaffed and filled into the silo, the plant cells continue to respire and in this process, a portion of the carbohydrate of the crop is oxidized to carbon dioxide and water with the production of heat. The inability of this heat to escape readily from the compact material accounts for the rise in temperature which occurs soon after filling the green chaff into the silo. Proteolytic enzymes pre-existent in the crop act on the protein constituent, causing it to be hydrolysed to amino acids to a marked extent. This change is illustrated by the data in Table I. for the composition of green oats, vetches and beans and of silage made from this mixture. It will be noted that storage of the crop in the silo is accompanied by a distinct lowering of the percentage of true protein and a corresponding increase in the amount of simple nitrogenous substances ("amides").

TABLE I.—Composition of green oats, vetches and beans and of oat, vetch and bean silage (dry matter basis).

	Green crop per cent.	Silage per cent.
Crude protein	9·69	9·86
Ether extract	4·09	5·24
Nitrogen-free extractives ...	51·22	47·88
Crude fibre	26·19	26·78
Ash	8·81	10·24
True protein	7·55	4·05
"Amides"	2·14	5·81

Ensilage of a green crop is invariably accompanied by the production of organic acids, which arise from the action of micro-organisms on the carbohydrate of the crop. The common organic acids in silage are acetic acid, propionic acid, butyric acid and lactic acid. The unpleasant smell of sour silage is due to the preponderance of butyric acid, but in unspoilt tower silage, butyric acid is usually absent altogether and lactic acid is present in excess of acetic acid. Good maize silage contains, on the basis of the wet material, about 0·4 per cent. of acetic acid, 0·9 per cent. of lactic acid and a trace of propionic acid.

The chlorophyll of the green crop is transformed by the action of the organic acids which arise during ensilage into the magnesium—free derivative phæophytin. The latter may vary from olive-green to yellowish-brown and brownish-black in colour. For this reason, the colour of silage is not a safe criterion of its quality.

Types of Silage.—Work carried out at Cambridge on the factors which influence the quality of silage arising from the conservation of the oat and vetch crop has enabled five distinct types of silage to be recognized, namely, sweet, acid brown, green fruity, sour and musty silage.

Sweet silage has a pleasant smell, not unlike that of over-heated hay, and is readily consumed by stock. It is formed when the temperature of the ensiled material is permitted to rise to 50° C. or beyond. At these temperatures, the fermentation in the silo is dominated by the lactic bacteria, and in consequence the main acid in sweet silage is lactic acid. To ensure the production of this type of silage, it is advisable to ensile a comparatively dry crop, either one owing its dryness to sufficient maturity, or one that has lost moisture as a result of wilting. Such fodder does not pack so tightly as is the case with sappy, succulent material and consequently retains more air. This circumstance leads to a more active cell respiration (an oxidation process dependent on air supply) and therefore to the attainment of higher temperatures in the silo. It should be noted in passing that the plant cells die at a temperature of 50° C., at which point cell respiration ceases.

Silage made in stacks is usually of the sweet type, since under these conditions air has much freer access to the material than when the crop is ensiled in a tower. In the so-called electro-silo used in certain parts of Germany, the production of sweet silage is brought about by raising the temperature of the ensiled fodder to 50° C. by the passage of an electric current.

Acid brown silage, possessing a pleasant, acidic smell from the presence of acetic acid, is perhaps the commonest type of silage produced in tower silos. It is obtained by ensiling a reasonably mature crop containing about 70 per cent. of water, the mown crop having been allowed to wilt for some hours before ensiling. The temperature during the fermentation rises to between 30 and 40° C. This type of silage, which varies in colour from yellow-brown to brown, is readily eaten by farm stock.

Green fruity silage, so called because of its olive-green colour and its attractive smell arising from the production of small amounts of fragrant-smelling esters during fermentation, is superior to acid brown silage in palatability and feeding value. It is formed when oats and vetches are ensiled in a medium stage of maturity, when the oats are in full milk and the vetch pods full-grown in length but with seeds barely half formed. It is essential to ensile the crop without wilting. The temperature of fermentation in this case is about 30° C.

Sour silage has a dark-brown to olive-brown colour and an

offensive "cheesy" smell due to the presence of butyric acid. To ensile a very immature, succulent crop is to risk the production of this very undesirable type of silage, since the sappy material settles down so compactly that air is too thoroughly excluded and the rise in temperature is small. The course of fermentation in these conditions is uncertain, and sour silage, containing a high percentage of butyric acid and little or no lactic acid, usually results.

Musty silage, which should never be used for feeding purposes, may arise when air has too free access to the ensiled crop, this leading to extensive spoiling as a result of mould activity. Such silage may be distinctly alkaline in reaction instead of acidic. In the tower silo, musty silage is only formed in the surface layer, but considerable wastage may occur in the stack from moulding, especially if the stack is carelessly finished off.

Feeding Value of Silage.—Sufficient evidence has been accumulated to show that the digestibility and feeding value of tower silage is about equal to that of the green crop itself and, on the dry matter basis of comparison, of hay made under good conditions from the same green crop. This statement is borne out by results obtained by H. E. Woodman in determinations of the digestibility and nutritive value of hay and silage made from a crop of oats and vetches.

TABLE II.—Digestion coefficients and starch equivalents of green oats and vetches, oat and vetch hay, and oat and vetch silage.

	Green oats and vetches. Per cent.	Oat and vetch hay. Per cent.	Oat and vetch silage. Per cent.
Dry matter	63·7	65·0	64·1
Organic matter	65·5	66·1	65·9
Crude protein	63·1	68·2	65·1
Ether extract	51·9	36·8	73·4
Nitrogen-free extractives...	76·5	71·3	70·5
Crude fibre...	47·6	58·7	57·1
Starch equivalent of 100 lb. dry matter (lb.)... ...	44·9	43·2	45·6

It will be noted that the hay, silage and green crop are digested to an almost equal degree. Indeed, storage in the silo appears to lead to a significant increase in the digestibility of the fibre in the crop. This finding, which has been noted generally in connection with the ensilage of green fodders, is of distinct economic importance, since silage crops usually contain considerable amounts of fibre. The high digestion coefficient of the ether extract of the silage is noteworthy, but in this connection it should be pointed out that the ether-soluble fraction of silage consists almost wholly of organic acids.

In feeding trials carried out at Cambridge with young cattle, oat and vetch silage has been shown to give slightly better results than hay made from the same oat and vetch mixture, the conclusion having been drawn that 100 lb. of silage containing about 70 per

cent. of moisture is equivalent to 35—40 lb. of hay containing about 15 per cent. of moisture.

Silage crops are frequently grown as a substitute for roots. It is desirable to point out, however, that roots and silage, although similar in respect of their succulent character, differ very considerably in chemical composition. From the results of extensive feeding trials, Drew concluded that 6 lb. of silage (oats, peas, beans and vetches) is able to replace 10 lb. of mangolds plus about ½ lb. of hay in the rations of dairy cows and fattening cattle. Further, the labour of feeding silage to stock is small compared with that involved in root feeding.

Silage is a valuable food, on account of its soft, succulent character, for weaning calves. It is a favourite material for inclusion in the rations of dairy cows and, when fed to fattening bullocks, produces the " bloom " on the coats which attracts the eye of the butcher. It is relished by sheep and may be fed in moderation, up to 14 lb. per day, to horses. On account of its fibrous character, however, it should never be given to pigs in more than very small amounts.

Losses of Nutrients During Ensilage.—The losses of food material which occur when a green crop is ensiled are the result of (1) the oxidation of a small part of the carbohydrate in the fodder to carbon dioxide and water as a consequence of cell respiration during the early part of the storage period ; (2) the fermentation of carbohydrates by bacterial agency ; (3) the carrying away of soluble food constituents in the juice which drains from the silo.

Where the requisite conditions for the making of good tower silage are realized, however, these losses are by no means excessive, certainly no larger than those which accompany the conversion of green crops into hay. With an oat and vetch crop containing about 70 per cent. of moisture, for example, acid brown silage can be made with a loss of food material equal to about 6 per cent. of the total dry matter in the crop. The loss entailed in the making of sweet silage in a tower silo is of the same order of magnitude. The production of green fruity silage leads to somewhat higher losses, namely, about 9 per cent. of the dry matter of the crop as ensiled. In this case, however, it is essential to cut the oats and vetches at a somewhat earlier stage of maturity, when the dry matter content may be from 23 to 26 per cent., and to ensile the crop without a period of wilting. A larger volume of juice, containing dissolved food material, drains away from the somewhat sappier crop required for this type of silage and the total losses are thereby enhanced. The superior nutritive qualities, however, largely compensate for this higher loss, the feeding values of green fruity and acid brown silage, lb. for lb. of dry matter, being roughly in the ratio 7 : 5.

The losses of food nutrient during ensilage may be much higher than those stated above when crops which are wet and sappy, either

as a consequence of immaturity or from the inclusion of rain, are filled into the silo. In such cases, the losses from juice drainage are augmented considerably. For example, the ensiling of green maize, with a moisture content of 80—82 per cent., entails a loss of about 15 per cent of the dry substance of the crop. In the case of sugar beet tops, containing from 85 to 88 per cent. of moisture, something like a quarter of the total dry matter is lost during the process of conservation. The losses may also be excessive when a too immature crop is ensiled with the resulting production of sour silage. Sufficient has been written in preceding sections to show that the losses in making clamp and stack silage must of necessity be very much higher than those which occur in tower ensilage.

The production of good tower silage with the minimum losses of food material may be assured when the dry matter content of the crop is about 30 per cent. If the crop is wetter than is represented by this figure, a period of wilting should be allowed after mowing to enable the fodder to attain a moisture content of about 70 per cent. In the case of the oat and vetch crop, for example, cutting at a moderately matured stage, followed by wilting for several hours, will yield fodder containing approximately this percentage of moisture. The silage from such material will be either of the sweet or the acid brown type, according to the temperature attained during the fermentation, the temperature in turn depending on the procedure adopted during the filling of the silo.

Precautions When Filling Tower Silos.—It is important that attention should be directed to the following recommendations which have been issued recently by the Ministry of Agriculture and Fisheries in connection with the avoidance of mishaps during the filling of tower silos.

(1) The crop should have reached the proper stage of maturity and should not be too dry. With an immature crop, the extent and nature of the fermentation that will take place is uncertain ; an abnormal volume of carbon dioxide or possibly other dangerous gases may be generated. On the other hand, if the material is very dry, it will not tread down closely ; the additional air so retained would cause the evolution of a larger volume of carbon dioxide than usual.

(2) The material that has been fed into the silo should be well trodden before work is closed down for the night, or for any considerable period during the day. The reason for this is that loosely-packed material will retain more air and therefore give off a larger volume of carbon dioxide than material that has been well trodden.

(3) No door should be sealed up, unless it is absolutely certain that the material will not sink below the level of the bottom of that door.

(4) Before work is resumed, whether in the early morning or at any time during the day when work has been suspended for

any length of time, the lowest door possible should be opened. No one should be allowed to enter the silo until a reasonable time has elapsed after this has been done.

(5) Where the silo is being filled by an elevator, as long an interval as possible should be allowed after the lowest door has been opened to allow any harmful gases to escape. When a blower is being used to fill the silo, this should be put on for a few minutes before anyone enters the silo, with the object of removing all the stagnant gases.

The composition of the gases resulting from the fermentation of the crop varies according to the material used. In exceptional circumstances, some of these gases might be of an inflammable character (as, for example, when marsh gas arises from the activity of cellulose-splitting bacteria). It is, therefore, necessary to add a warning to farmers not to adopt the common method of ascertaining whether air is foul, namely, that of lowering a lighted candle; for should any inflammable gases be present, an explosion might result.

NOTE.—The reader who wishes to pursue the subject beyond the limits of this chapter should consult "Ensilage," Bulletin No. 37, Ministry of Agriculture and Fisheries.

HAYMAKING.

Haymaking is the operation whereby grass and clover crops are converted into dry fodder. It includes the three processes of (1) Cutting; (2) Making; (3) Carrying.

Cutting.—Meadow hay is essentially a straw crop, the object being to secure it before the grasses begin to ripen their grain—that is, before the nutrient ingredients in the stem have migrated upwards to aid in maturing the seed. Hence, hay should be cut at about the time the bulk of the grasses are coming into flower—that is, just before the pollen dust can be freely shaken from them. If cut later not only does the quality deteriorate but early seeding weeds such as yellow rattle and soft brome grass tend to increase in quantity.

The mowing machine is employed wherever practicable for cutting hay, though the scythe has still to be used in water meadows and on steep or rocky slopes. The introduction of the mowing machine has increased the risk lest too much grass be cut at one time for the available hands to deal with, so that this is a detail requiring attention. The labour of mowing with the scythe is very severe, and it brings into play nearly every muscle in the body. An experienced workman will mow from threequarters of an acre to two acres per day, according to the heaviness of the crop. The line or row of cut herbage as it falls upon the ground is called the swath.

There is a notable difference in the mode of cutting by the scythe and by the mowing machine. The simpler implement effects

the clean cut of a knife. The machine, which works on the scissors principle, not only cuts, but crushes or bruises at the same time. The cut of the scythe is regarded as being the less injurious to the standing plant, and some farmers always prefer the scythe for meadow hay.

Making.—The conversion of green grass into hay is effected by loss of moisture, which is brought about partly by the sun's heat and partly by the wind. How great is this loss may be gathered from the circumstance that freshly-cut grass contains from 70 to 80 per cent. of water, whilst hay has only from 14 to 16 per cent. To promote the escape of water vapour it is necessary for the cut herbage to be turned over and shaken out, in order to expose as large a surface as possible to the air. At the same time, the work should be carried out in such a manner that, on the approach of rain, the material can be quickly gathered together, so as to expose the least possible surface to its action. Hence there is plenty of room for skill in the operation of haymaking.

The grass falls from the mower in thick swaths, which, if left undisturbed, would at length rot inside. Therefore they must be tedded—*i.e.*, shaken out or turned over in some way. This is done either by the hand-fork, or by means of a tedding machine, or a swath-turner.

It must here be remembered that the methods of haymaking have undergone considerable changes of recent years. Formerly the grass was all cut with the scythe, and afterwards tedded out with the fork. The process of haymaking in these circumstances being entirely carried out by hand was tedious and expensive.

The next step in advance followed on the introduction and development of labour-saving machinery, when the mowing machine, the horse-rake, and the "tedder" came into common use on the farm.

More recently other implements have gradually been added to assist in the hayfield, so that we now have the "swath-turner," "side-delivery rake," "hay-loader," and "sweep-rake," together with the "elevator" and hay-fork, which can be used under suitable conditions to minimize labour in saving the hay crop.

A large portion of the hay crop is made in the southern portion of England in the "swath" by means of the swath-turner. When sufficiently dry the swaths can be run together by means of the side-delivery rake into parallel rows across the field known as "wind-rows," which can easily be split up into cocks when necessary as a protection from the weather; or the hay can be loaded directly from the wind-row into the carts and waggons. During a wet summer, however, and when the crops of grass are heavy, the tedder will be found to be a machine that it is almost impossible to dispense with.

The process of making meadow hay when the tedding machine is used may be described as follows.

The crop, when ready, is cut with the mowing machine, the

grass being left in the swath, so that the water may evaporate from the surface. The next day it is "tedded," or spread out in a thin layer over the surface of the ground to dry. Sometimes when the grass is cut early in the morning, and the weather is fine, the tedder is set to follow immediately after the mowing machine. The next operation is "hacking," or collecting the hay together into small wind-rows, which may be run together into small "pooks" or "cocks" for the night.

The following morning these are thrown out into beds as soon as the ground is dry, and the tedding machine may be again set to work along these beds, if necessary.

The hay is then collected by means of the horse-rake into large wind-rows, which can be run up into large cocks for the night, or the hay can be carried direct from the rows as circumstances require. If put into large cocks, these should be turned over the next day as soon as the ground is dry, and if the weather is fine the hay should be fit to cart the same day.

The foregoing instructions apply to a period of fine weather, and would occupy a period of some three days. When the weather is unsettled or catchy, however, the period for carrying out these various operations has to be considerably extended ; and it may be necessary to continue the process of throwing the hay out into beds, and cocking it up again for several days in succession.

If hay is carted before it is ready, it may cause serious trouble by overheating when put together in the stack.

Carrying.—The hay is carted from the field to the stack in carts or waggons, the material being loaded on to these by hand. In some cases a machine of American origin, working on the elevator principle, and called a hay-loader, is used for picking up and putting the hay on to the carts, thereby making the process of haymaking less dependent on manual labour.

Another labour-saving implement, also introduced from America, the use of which is gradually spreading, is the sweep-rake (p. 64). This machine, which consists of a large frame on wheels drawn by two horses or a tractor, is able to sweep up the hay out of the cock or wind-row and take it straight up to the rick, thus saving the expense of carting. Its use is restricted, however, to cases where the stack is built in the same field from whence the crop is taken.

The time when hay is fit to carry and put into the stack will depend very largely on the bulk of the crop and the character of the herbage. When hay is composed of grasses of a somewhat dry and benty nature, it is not necessary to be so careful about its condition when carting as when dealing with a crop in which there is a large percentage of bottom growth and clover. In this latter case discretion must be used, as otherwise excessive heating, and in some cases spontaneous combustion may take place in the stack.

In the damper climate of the north of England and Scotland the custom is to put the hay up into large cocks or "summer ricks"

in the field, containing half a load to a load, with the object of allowing the hay to dry more thoroughly and sweat to a certain extent before it is carted some weeks later to the large rick. This method also has the advantage of saving time in securing the hay crop at a busy time of the year, the final carting and building into stacks being left till a favourable opportunity presents itself.

The ordinary stacker, or elevator, will be found most useful for emptying the carts on to the stack, and will save a lot of manual labour in pitching, especially when the stack rises in height. The hay-fork worked by means of a pulley from a cross-piece attached to a long pole set in the ground, will also be found a valuable implement when stacking hay, as it is able to raise a large part of a load from the cart on to the top of the stack at one lift.

Care must be taken in building a stack that the middle is kept as high as possible, otherwise the roof will become too flat when the stack settles down, and the thatch will be unable to remove the water sufficiently rapidly. The walls should also be carried up in such a way that the eaves stand well out from the base, so that the drip from the roof may fall clear of the sides.

General Haymaking Rules.—To obtain the best results attention must be paid to the following points in carrying out the process of haymaking.

Throughout the entire operation the crop should be dealt with as gently as possible. Turning and shaking out are, of course, necessary to assist the process of drying, but rough handling should be avoided. Grasses are covered with a delicate waterproof coating of waxy material, and when this is broken or injured water will soak into the stalks, and the quality of the hay will be much damaged by the soluble ingredients being washed out. This loss is especially liable to take place when half-made and tedded hay is washed by rain. The proper time to cut is when the bulk of the grasses and clovers are coming into flower, and before they set their seed. In this connection it must be remembered that any loss of weight in the crop by early cutting will be gained in the aftermath. Much greater damage, however, will be done to hay by cutting and allowing it to be washed for days by rain than by allowing the grass to become somewhat old before cutting.

In making clover hay great care must be taken to handle it as little as possible, and it must not be tedded, otherwise much loss may occur by breaking off the fine leaf. It is best, therefore, to let the crop remain a few days in the swath after it is cut to allow the upper surface to dry thoroughly, and then to gently turn it with the hand-rake or swath-turner, so that the under surface may be exposed. After a time it may be turned back again, and then gently put together in rows—three or four swaths being put into one row—from which, when fit, it should be carted direct, and putting it up into cocks should be avoided, if possible.

Lastly, it is a good rule to observe, and one of great importance now that, by means of the mowing machine, so much grass can be

cut in a day, that no more hay should be got on the ground than the staff at command can work.

Sweating.—When put together in the rick certain chemical changes take place in the new hay which give rise to the production of heat and sweating.

The amount of heat developed in a stack will often largely determine the quality of the hay when it is cut out. The fermentation which takes place in the stack is brought about by the starch in the grass being changed first into sugar, and then passing through the successive stages of alcohol, acetic aldehyde, and finally acetic acid.

Overheating is due to an excessive development of a suffocating, inflammable gas known as acetic aldehyde, and where this occurs not only may the hay be charred and its qualities for feeding spoilt, but spontaneous combustion may even take place in the stack.

A good sweating will often improve the subsequent quality and palatability of hay of a somewhat coarse character when put together, but the fermentation should stop at the sugar stage; and to obtain this the hay must be dry and in good condition when stacked.

The temperature of the stack can be tested by means of a thermometer, and a good sweating can be safely allowed up to 140° F. Danger is to be expected, however, if the temperature rises above 150° F. Where this occurs it may be necessary to cut a hole in the stack to allow the air to enter, or even in some cases to turn the stack over again.

CHAPTER XV.

HARDY FRUIT CULTURE AND MARKET GARDENING.

For good or ill, the present generation finds itself living in an age of mass production; an age when both the necessities of life and the luxuries of civilization tend to be produced cheaply and in vast quantity, standardized and available in continuous supply. This state of affairs, which appears to be an inevitable accompaniment of European and American civilization, in its present stages, is responsible both for the hundreds of acres of glass-houses in the Lea Valley and for the huge stretches of apple orchards in North America.

Cereals and meat can be grown on mass-production lines, but without a radical change in our agricultural methods and possibly in our climate, changes which are unlikely to take place, they cannot be grown on those lines in this country.

On the other hand, turning to commodities which are not regarded as staple foods, such as fruit and vegetables, we find that mass production is possible; is, indeed, actually in being in the case of apples, tomatoes and cucumbers.

There seems little doubt that, at present, fruit and vegetables offer a better chance of profit than agricultural crops. In these circumstances more and more farmers are considering the practicability of growing fruit or of adding vegetables to their rotations. Either step should not be taken without careful consideration, and an attempt will be made in this section to present the case for fruit-growing, and in a subsequent section the case for market-garden crops.

Obviously in the small amount of space that is available full details of all the operations carried out in fruit growing cannot be given : whole books could be written, and have been written, on pruning alone. But it will be possible to discuss briefly the various problems of the fruit grower, to point out where detailed information is to be obtained, and to issue a few warnings against a too hasty plunge into what is by no means a sure and simple way of earning a living.

There is to-day no room for the careless or inefficient fruit grower. Confronted by highly skilled competitors, home, colonial, and foreign, and by altered labour conditions, he cannot pick up a living with a minimum amount of effort as once he did. For a farmer the change-over to horticulture will involve the acquisition of a new technique. If he decides to grow fruit he must also decide to grow it well, and growing good fruit is now a highly specialized industry. In addition to skill and experience, capital is needed, for a fruit grower is more highly capitalized than a farmer. It is well also to realize that growing good fruit is only half—probably less than half—the battle : one must know how to sell it.

There are many factors to be considered and neglect of any one of them may quite easily mean failure. Caution is required in choosing a location : a district may be very suitable for horticultural crops but it may be inaccessible. Good road and rail communications are essential.

A plentiful supply of water is necessary. The spraying of fruit trees has now become a routine operation, and in order that it may be carried out economically water should be at hand. Special buildings will probably be needed for storing and packing fruit.

A horticulturist uses more labour than does a farmer. And this labour is of a special type : not necessarily more skilled than agricultural labour, but different, and therefore not always available. A grower may have to train his own labour : spraying, pruning, picking and packing—all essential operations—do not come within the province of the agricultural labourer.

A special warning is necessary as to soil. A skilled horticulturist can grow fruit and vegetables almost anywhere. But it is not difficult to imagine certain circumstances in which his crop may cost far more to produce than it is worth on the market. It is no use attempting, if one has an unsuitable soil, to compete with men who are growing fruit on soils which the experience of generations of growers has proved to be highly suitable for that purpose.

Again, a warning is needed as to climate. There are many parts of this country where it would be hopeless to attempt to grow highly coloured dessert fruit; and others where the occurrence of spring frosts almost rules out the profitable production of either apples, plums or pears.

Finally, one must remember that horticultural produce is mostly of a highly perishable nature: much of it must be marketed at once, regardless of the state of the market. The demand fluctuates enormously, varying with the district and even with the weather. "Gluts" occur to complicate matters: when everybody has a good crop of Victoria plums—a crop which must be marketed at once—prices fall, often to such a low level that it is not worth while picking the crop.

Against these warnings may be set a few facts of a more cheerful nature. Supplies of home-grown fruit are still inadequate. There is a market for good produce ready made by foreigners and colonials. A taste for fruit has been developed by cheap foreign produce, and this taste shows no signs of declining. In addition, jam factories offer an outlet for the disposal of fruit, and recently the voice of the canner has been heard clamouring for English fruit of high quality.

Preliminary Considerations.—One of the chief things to consider before planting fruit is the question of the disposal of the crop Roughly, the markets available are of two types: (*a*) local markets and (*b*) distant markets, *i.e.*, in London or large provincial towns. Type of market will dictate to a great extent the nature of the crop grown: obviously, for a distant market a bulk of a few well-known commercial varieties of fruit is desirable, whereas for a local trade it may be necessary to grow a wider range of varieties. The man with the large acreage is naturally concerned with the more important markets, while the man with a few acres will be wise to concentrate on some local outlet for his produce.

Interwoven with the question of markets is the equally important question of transport. A small grower supplying a neighbouring town will probably solve this problem without difficulty, but a large-scale grower who wishes to rush heavy consignments of perishable produce to distant parts of the country needs first-class transport facilities.

A location suitable in every other respect for fruit growing will be useless if means of transport are lacking; and on the other hand, districts with not specially suitable soils may be valuable because of the facilities they offer for rapid transport.

Having settled in his own mind the type of market he wishes to supply, and the method he is going to adopt to reach that market, the prospective grower can turn to the consideration of a rather formidable list of factors which he cannot afford to neglect.

It is a fact not without significance that we have in this country certain "specialist areas" where fruit or vegetable growers tend to congregate. On investigation it usually turns out that these areas are situated on special types of soil which experience has

shown will grow fruit or vegetables successfully and with a minimum of trouble. It has been said that a successful horticulturist can grow fruit almost anywhere. But in order to make a living it is necessary to grow *good* fruit and to grow it as cheaply as possible.

Hence a "fruit-soil" is one that is easily worked, well-aerated, well supplied with water, and with free natural drainage. It would, however, be unsafe to dogmatize on the subject of fruit-soils, since by a right choice of kinds and varieties of fruit and of methods of growing it, fruit-growing may be made profitable outside the specialist areas. There is not sufficient information available to enable definite recommendations to be given; and to embark on fruit-growing in a new district is therefore bound to involve a certain amount of risk. An agriculturist usually has behind him the accumulated experience of generations of farmers but, unless his land is actually in a fruit- or vegetable-growing area, his change-over to fruit should not take place without very careful consideration.

Soil may be suitable and transport facilities ample, but there remains the important question of climate. There are certain places in the North of England where fruit of commercial quality can be grown successfully, but it is significant that most of our fruit is grown south of Lancashire and Yorkshire. High rainfall, lack of sunshine, late spring frosts, have played an important part in restricting successful commercial fruit-growing to definite portions of this country. A high rainfall and a cool climate may be countered to some extent by cultural methods and choice of kinds and varieties of fruit, but there is no practical way of countering frosts when trees are in bloom.

Even in favoured parts of the country "frost-holes" are found: depressions into which cold air drains and accumulates. Free air-drainage is essential, and an orchard exposed to wind and weather is preferable to one buried in an undrained hollow.

It will be seen that planting up fruit is not an adventure to be embarked on lightly. Even if every condition—soil, climate, transport facilities—appears favourable, it is well to remember that there are few English villages and towns where American, colonial or continental fruit is not in competition with home-grown produce. It is a poor village shop that cannot supply a pound of "Jonathans."

Kinds and Varieties of Fruit.—Commercial fruit is divided into "top" and "soft." Apples, pears, plums and cherries are "top" fruit; black currants, raspberries, gooseberries and strawberries are classed as "soft" fruit.

In considering the question of varieties the beginner must get rid of the idea that what he prefers is likely to be what the salesmen and retailers prefer. In his own garden it is quite probable that Worcester Pearmain, coarse and wooden in texture, poor in flavour, is not considered worthy of a place; and that Irish Peach supplants the soft and showy Mr. Gladstone. But let him not think that he can impose his personal taste on the market.

Wooden though it be, Worcester is wanted, and in quantity, and it would be courting disaster to plant up Irish Peach in the hope of ousting Gladstone from the salesman's affections.

Whether we like it or not, modern business methods involving mass production, standardization and continuity of supply must now be applied to fruit-growing. And the application of these methods has the effect of rigorously cutting down the number of varieties grown. From the hundreds of varieties of apple in existence in this country, many of which are of really first-class quality, a mere handful stand the test of commercial conditions.

Turning to the question of what kinds of fruit to grow, and excluding the luxury trade and special lines, it is probable that at the present moment apples, plums and strawberries would offer the farmer the nearest approach to a sure and certain reward for his efforts, and would involve him in a minimum of technical difficulty. Cherries and pears need special soils and climatic conditions ; black currants and raspberries, once very profitable crops, have lately become less safe ; gooseberries are only worth attempting in a early warm district for the green berry trade. It should be remembered, however, that circumstances may be such that it would pay a beginner to leave the beaten path and take up some special line or lines. He may be favourably situated with respect to soil and climate ; or he may be next door to a market, say in some seaside resort, which is waiting to be exploited.

Apples.—In a short article it would be impossible to describe fully the different commercial varieties. For such descriptions the reader must be referred to the pomological works included in the bibliography at the end of this chapter.

The list of commercial varieties which have proved suitable for modern conditions and which are known to salesmen and retailers throughout the country is a short one.

VARIETIES FOR COOKING.

Emneth Early (Early Victoria).	Lane's Prince Albert.
Stirling Castle.	Newton Wonder.
Grenadier.	Bramley's Seedling.
Lord Derby.	

VARIETIES FOR DESSERT.

Beauty of Bath.	Worcester Pearmain.
Mr. Gladstone.	Allington Pippin.
Devonshire Quarrenden.	

This list of dessert varieties can be extended by the addition of James Grieve, Charles Ross and Cox's Orange Pippin. These varieties, however, require special care in culture and presentation, and it is useless to attempt them unless this fact is realized. Unless suitable soil and climate are available, Cox's Orange Pippin should not be planted by a beginner in fruit-growing. And, it may be added, no beginner should dream of planting any fruit without first utilizing every possible source of advice, not excluding that of the labourer who has spent a life-time working on the land.

Plums.—The list of plums suitable for mass production is even more restricted than that of apples. None is of dessert quality: they are simply varieties which have proved suitable for market conditions and that is the best that can be said about them.

Czar.	Victoria.
Purple Pershore.	Monarch.

Of all market plums Victoria is probably the best known and most popular. When well grown and fully ripe it is quite edible in the uncooked state. Fully ripe Victorias, or rather, Victorias which have ripened on the tree, are, however, not obtainable on the market since plums for market must be picked before they are ripe.

To this list might be added River's Early Prolific ("Early Rivers"), Yellow Egg (or Pershore), Pond's Seedling, and Belle de Louvain. River's Early Prolific is the earliest and most profitable market plum; it is, however, self-sterile (*i.e.*, requires to be pollinated by another variety of plum), and has the reputation of being an erratic cropper. Yellow Egg, a cheap inedible fruit only suitable for jam, is a very heavy cropper and when plums are scarce may be profitable. It is self-fertile (*i.e.*, will fruit freely when fertilized with its own pollen).

In some districts, Pond's Seedling and Belle de Louvain succeed, and may therefore be worth planting.

It is, of course, hardly necessary to add that if the grower is catering for some local market it will pay him to extend his list by the inclusion of varieties which do well in his district and which fill in gaps in the supply of standard varieties. Continuity of supply is of supreme importance when a local trade has been built up, and it is as well to have several strings to one's bow so that in the event of the crop failing in the case of certain sorts there may be a chance of a return from others, hence one sees on the market such plums as Black Diamond, Coe's Late Red, Prince of Wales, Cox's Emperor, Kentish Bush, Red Myrobalan and Green Gage.

In districts where they succeed, Green Gages (picked when unripe) are profitable. They should not be planted in districts where low temperatures are the rule at blossoming time.

Pears.—At present, late autumn or early winter pears have ceased to be really profitable on account of heavy importations from America and South Africa. If he is in a warm district (for it is useless to plant pears for market where climatic conditions are such that only in one year out of five pear blossom escapes being frozen), the beginner should concentrate his attention on early pears which will be on the market before the carefully packed and graded consignments begin to pour in from abroad.

Again the list of suitable varieties is a short one. Known to every salesman are the following:—

Dr. Jules Guyot.	Fertility.
William's Bon Chretien.	Conference.

During the course of generations certain varieties of fruit have impressed their names on the public mind. One of those names is the "William" pear; hence an effort should be made, if pears are grown at all, to include William's Bon Chrétien in the list of varieties. An effort is required for, although this is an early pear of high quality and a good grower, it is a martyr to the disease known as "Pear Scab." This disease is, however, controllable by modern spraying methods. Dr. Jules Guyot, though much inferior in quality, is practically scab-proof.

Both Fertility and Conference are pears suitable for mass production. Fertility is (as its name suggests) a really good cropper but is of poor quality: not admissible to the private garden, but indispensable to the market grower. Conference, of better quality and resistant to the attack of scab, is another of the varieties that a beginner in pear growing will find to be indispensable.

There is, needless to say, a long list of high quality pears which are mostly found in private gardens and, as a rule, on walls. Of these, Doyenné du Comice, which in quality corresponds to Cox's Orange Pippin among apples, is only worth attempting in warm positions and suitable soils. This pear is as well known on the markets as Cox's Orange and fetches high prices (when properly presented and well grown), but the rest of the list should be ignored by all save specialists.

There is a class of poor quality early pears, including such varieties as Lammas and Chalk, which sell well in seaside towns during the season; but they should not be planted unless a certain local sale is assured, for it would be useless to send them to more sophisticated markets.

Root Stocks and Propagation.—The varieties of cultivated fruits with which the fruit grower is concerned are not simple in genetic constitution. A Victoria plum, when its flowers are fertilized with their own pollen, produces seeds which give rise to trees unlike their parent: they are not Victoria plums and indeed may not bear the slightest resemblance to that variety. Obviously, in the case of varieties which are not fertile with their own pollen but require pollen from another variety to enable them to set fruit, the results of seed sowing is to produce varieties widely divergent in character from their parents. But for commercial fruit-growing a small number of definite varieties is needed, hence sowing the seeds of cultivated fruits is ruled out as a method of propagation. To obtain an orchard of Worcester Pearmain trees it is necessary to adopt the method of vegetative propagation; that is to say, portions of the original variety are removed in the form of buds or branches and induced to develop into complete trees. And it should be realized that although an apple such as Cox's Orange Pippin is grown by the thousand in England, Australia and America, all these thousands of trees must be regarded as parts of one individual: for only one Cox's Orange Pippin has ever made its appearance on this planet.

This is not the place for a treatise on the technique of

propagating fruit trees by the methods of budding and grafting, nor are these operations best carried out by the beginner; the reader is therefore referred to the bibliography at the end of this chapter for sources of information on these subjects.

Although a fruit grower generally relies on a nurseryman for obtaining his trees, it is necessary for him to know something about the question of root stocks.

It has been said that in order to propagate, say, Worcester Pearmain, portions of the original tree are removed and induced to develop into separate trees. These portions of the original tree are not made to form roots of their own but are budded or grafted on another fruit tree having already a developed root system. This individual is called a "stock."

It would be highly improbable that this stock should have a type of root system even approximating to that of the original Worcester Pearmain tree; and it would therefore be too much to expect that Worcester Pearmain, now furnished with a root system appropriate for a different type of apple, should behave as though it was on its own roots.

We are, therefore, brought up against the problem of the influence of the stock on the "scion" (*i.e.*, the bud or graft taken from the original tree). As to the question of the influence of the scion on the root not much is known at present, and this question may be safely ignored. That the behaviour of the scion is definitely influenced by the nature of the root system with which it is joined is now well known, and this fact is of very great importance to the fruit grower.

A stock may influence a scion in the following directions:—size of tree, precocity and colour of fruit. The stocks themselves may vary in size and strength of root system, and therefore in their power of anchoring a tree to the soil. It is not desirable that the trees of Worcester Pearmains in an orchard should be of different sizes, some no bigger than currant bushes and others with a spread of twenty feet; nor, for mass production, should they vary in time of ripening. Clearly then, in addition to standardized scions we need standardized stocks. And standardized stocks are obtained by the method of vegetative propagation: in this case by means of layering, stooling, cuttings, or root-cuttings.

The chief point for the grower to realize is, that by means of a right choice of root stock, he can, in normal conditions, have either a plantation of dwarf apples of a given variety spaced nine feet apart, or one of large trees needing twenty or more feet between them.

For practical purposes it is only necessary to consider three types of vegetatively propagated stocks.

(*a*) *Very dwarfing stocks.*—In this class only one type is of importance: Jaune de Metz (Type IX. of the East Malling Research Station, where the greater part of recent research on stocks has been carried out).

(b) *Semi-dwarfing stocks.*—Here, again, the practical man need only consider one type : the Doucin (Type II. of the Malling classification).

(c) *Vigorous stocks* suitable for producing large well-rooted trees. Two promising types (numbered XIII. and XVI.) have been isolated and are being propagated and tested at East Malling.

In the case of (a) and (b) the behaviour of trees has been under observation for at least sixty years, and results can be predicted with some confidence. Class (c), however, is under trial. The research workers who have selected these stocks will not live to see the behaviour of mature trees worked on them : fifty years hence it may be known whether their choice was justified or not.

Type IX. may be considered a specialist's stock. Trees on IX. bear early and heavily, make very little wood, have a feeble anchorage in the soil and produce high quality fruit. It is a specialist's stock in that trees on it need attention to such points as pruning, feeding, thinning of the crop and staking. On the other hand, nobody should be deterred from planting trees on IX. by these considerations, for returns from them (provided conditions are favourable) are very high. A point which should not be overlooked in connection with this stock is its power of accelerating the ripening of certain varieties by about ten days or so. One of these varieties is Beauty of Bath ; this is already an early variety, and the extra earliness conferred by Type IX. greatly enhances the value of the crop.

Type II. is used when permanent " bush " (*i.e.*, short-stemmed) apple trees are required, and, like Type IX., is chiefly of value for dessert varieties when quality rather than quantity is the end in view. As in the case of trees on IX., trees on this stock will need pruning, spraying, cultivation and feeding, if good results are to be obtained. It is unlikely that a neglected plantation of trees on Type II. would give results worth having.

Little can be said safely as to the future of trees on Types XIII. and XVI., and in view of this fact, when strong growing varieties are to be planted and large trees are required, the old practice of using seedling or " crab " stocks must be given consideration. It has been said that owing to the fact that every seedling apple is a separate and distinct individual, scions of any one variety of apple worked on a collection of seedling stocks cannot be expected to behave in a uniform manner : some stocks may have a dwarfing effect on the scion, while others may produce very vigorous trees. This disadvantage is overcome to a large extent in actual practice by selecting the more vigorous young trees after they have reached the age of at least three years. For generations this practice has proved successful, and the uniformity of orchards budded on seedling stocks is often a source of surprise to pomologists who are familiar with the diversity of types encountered in a batch of seedlings. In addition, recent research seems to indicate that

after the lapse of years the scion may gain ascendancy over the stock.

Where large, vigorous trees are required, and where trees are required for heavy soils that are penetrated with difficulty by the fibrous root systems of vegetatively propagated stocks, it is probable that seedling stocks will continue to be used until the value of Types XIII. and XVI. have been demonstrated.

In the case of plums both vegetatively propagated and seedling stocks are used commercially, though certain varieties (such as Yellow Egg and the Cambridgeshire Green Gages) are grown on their own roots. No stock having a dwarfing effect comparable to that of Jaune de Metz is used commercially. Moreover, since all the more popular market varieties of plums are only fit for cooking, bulk rather than a small quantity of highly finished fruit is naturally the aim of the grower, and dwarfing stocks are therefore not needed by him.

The effect of stock on scion is not manifested in so spectacular a manner as in the case of apples. Myrobalan stocks give large, soft-wooded trees, late in coming into bearing, susceptible to Silver-Leaf attack, suitable for poor soils, and eminently suitable for nurserymen who require in a minimum of time large saleable trees. Trees on the Common Plum stock are smaller and harder-wooded than those on myrobalan ; they are said to be less susceptible to Silver-Leaf disease and come into bearing earlier. The Mussel and St. Julien stocks also appear to exercise a slight dwarfing effect.

A point to be borne in mind is, that not all stocks are suitable for certain plums ; Czar, for instance, will not grow on Common Plum or Brussels stocks, nor will damsons.

The grower should not merely order plum trees from a nurseryman but should take into consideration the questions of variety, soil and water conditions, and then (after receiving advice from an expert) should specify the stock on which he requires his plums to be worked. This proviso, of course, applies equally well to the purchase of apple or pear trees.

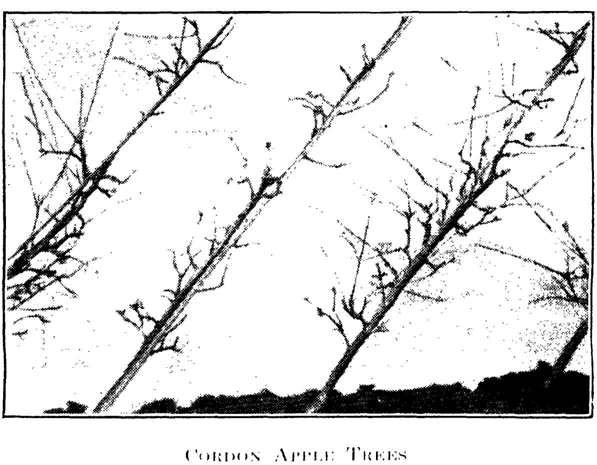
For pear trees, in modern commercial conditions, only one stock is needed : the Quince. Formerly, when standard or half-standard pears were planted, and when the planter was prepared to wait fifteen years or more for a crop of fruit, seedling pear stocks were used, and what has been said about the disadvantages of seedling apple stocks applies with equal force to pears.

The quince stock is a dwarfing stock, and trees worked on it are not only much smaller than those worked on " Free " or seedling stocks, but come into bearing more rapidly ; moreover, their fruit is more highly coloured. The term " quince stock " is an inclusive one, and it has been found at East Malling that not all quince stocks are desirable. Malling Type A (the Angers quince) is probably the most suitable, and purchasers of pear trees should specify this stock when ordering their material.

PLATE I.

STANDARD APPLE TREE.

PLATE I.—*continued.*



Cordon Apple Trees

Planting.—Having selected his soil and site, and having chosen his kinds and varieties of top fruit, the grower can pass on to the actual planting up of his ground.

In text-books prominence is often given to such preparatory operations as draining, liming, sub-soiling and clearing. It is possible, of course, to grow fruit on land that is in need of drainage, but such land is not fruit land. To avoid expense and the not remote possibility of ultimate complete or partial failure, it is advisable to choose for fruit land which is not in need of drainage. As for sub-soiling, if centuries of shallow ploughing have left a "pan" it will be well to break this up; but if there is merely a thin skin of cultivable soil lying on an unkind sub-soil, no amount of sub-soiling will make fruit trees feel at home. A good depth of well aerated soil is necessary for success. There is no experimental evidence to show that liming is necessary for top fruit; and if the soil texture is so bad that lime is needed to ameliorate it, such soil is not suitable for high-class fruit-growing.

In short, before planting fruit, we should make certain that the soil is deep, well-aerated, naturally drained, and free from troublesome perennial weeds. Land which needs expensive cultural operations to fit it for fruit should be avoided.

If his selected location is in an exposed district, the far-seeing grower will have planted, several years in advance, a wind-break to protect his young trees, but in actual practice wind-breaks, other than ordinary farm hedges, are seldom seen. A very important point, however, is the protection of young trees from rabbits and hares, and there are few districts where a rabbit-proof fence is not needed

At this point a sentence from "Modern Fruit Growing," by W. P. Seabrook, may be quoted with effect: "Mass production of a large bulk of few varieties at the lowest possible cost and of the highest possible grade must be the aim of every intending planter." To achieve this result it is clear that a great deal of forethought and preliminary planning is needed. The questions of soil, climate, location and varieties have already been considered; there remain for consideration such points as size and shape of trees, their arrangement and distance apart. The orchard when planted should be susceptible of easy cultivation and, if possible, of tractor cultivation; and its trees should be chosen and arranged so that inter-pollination can easily take place (for although certain varieties will set fruit when self-pollinated, it is generally agreed that they prefer pollen from another variety). These points will dictate the actual lay-out of the plantation.

First needing consideration is the question of size and shape of tree. Commercially, three types are mostly used: (1) "Bush" trees with short stems, and branches commencing at a height of from two to three feet above ground level; (2) "Half-Standard" trees having a stem free from branches to a height of about four feet six inches; (3) "Standard" trees with a clean stem about six feet high.

When high quality fruit is desired the bush tree is almost universally adopted not only in this country but abroad. Obviously, these trees on half-dwarfing stocks are more easily managed than standard trees which may require to be spaced at forty feet apart. The operations of pruning, spraying, thinning and picking present a minimum of difficulty.

The half-standard type of tree is chiefly adopted for plums, and particularly for those weak-wooded, heavy-cropping varieties (such as Victoria or Purple Pershore) which, after a few years of fruiting, take on a "weeping" habit of growth. If it is adopted for apples the grower must remember that the larger the tree the more difficult and expensive become the numerous operations needed to check the ravages of pests and diseases.

Standard trees of strong-growing apples are used for grass orchards, or for plantations where vegetables or other low-growing crops are of importance. But they are in the highest degree unmanageable, and though producing heavy crops when mature, these crops are usually composed chiefly of low-grade fruit.

The "Cordon" type of tree, a single stem at an angle of 45° to the ground, supported by a stake or trained to wires, is only used for the production of the highest grade dessert fruit, and a plantation of cordons requires expert management if it is to be successful.

Pears are nowadays grown as bushes and on quince stock. Cherries of the so-called "sweet" varieties are grown commercially as standards in grass orchards. They are worth consideration if soil and locality are known to be suitable.

Formerly, when hand labour was cheap, various methods of arranging trees which practically precluded the effective use of horses or tractors were in vogue. An instance of this is the "triangular plant" (Fig. 54).

Nowadays all orchards are planted on the square system. This not only facilitates cultivations but, in the event of trees reaching a larger size than was anticipated, enables thinning to be carried out effectively, whereas a triangular plant cannot be thinned satisfactorily.

The distance apart at which trees should be planted is dictated by various considerations. Not all varieties of apple are of equal vigour: the difference between trees of Cox's Orange Pippin and Bramley's Seedling worked on the same type of stock is a very wide one. Similarly, varieties of fruit trees vary in what is known as "habit of growth": some adopt an "upright" mode of growth in their youth, while others are "spreading." Choice of stock will also influence distance of planting: bush trees of Bramley's Seedling on Type II. may, on a particular soil, be planted twenty feet apart, but standards of the same variety on seedling (or "Crab") stocks may need thirty feet or more.

The question of pollination is of great importance. It would, for instance, be a disastrous experiment to plant up a block of several acres of Pond's Seedling plums. Such an orchard would produce

annually a plentiful supply of wood but next to no fruit, for the reason that Pond's Seedling is self-sterile and will therefore fail to set fruit unless its flowers receive pollen from another variety. Some varieties are only "partially self-fertile," and here again the best results are obtained when pollen from other varieties is available. In planning out an orchard of no matter what kind and

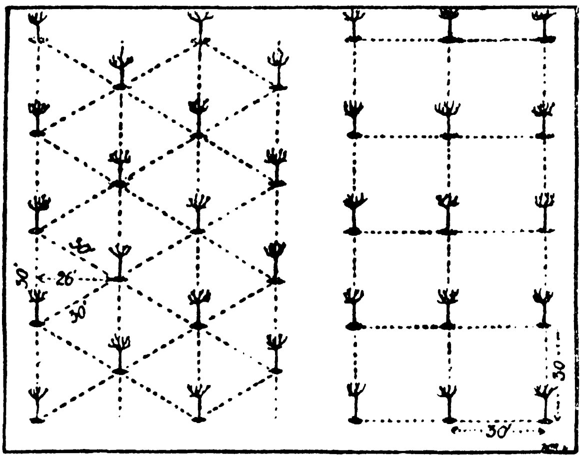


FIG. 54.—ARRANGEMENT OF ORCHARD, showing trees planted in equilateral triangles and in squares.

variety of top fruit, this question of pollination must be given consideration. When sweet cherries are planted a mixture of varieties is essential; all the sweet cherries grown commercially are self-sterile and, moreover, have "pollen preferences": that is to say, it is not enough that they should receive pollen from another variety, they must receive it from a particular variety.

A good deal of research has been carried out on the subject of the pollination of fruit trees, and sufficient information is now available to enable the modern grower to avoid the mistakes made by his predecessors.

As to the transference of pollen from one variety to another: this is effected by insects, the hive-bee being the most valuable agent. Unfortunately, the modern hive-bee does not stir abroad in cold weather and in some seasons acres of plum trees may be seen in bloom with not a bee to fertilize their flowers. It would be well worth while for the English grower to imitate his American rival and instal colonies of bees in his orchards, for even in cold weather there may be an hour or two during which bees are able to work. Wind may be disregarded as a pollinating agent, and at the time when pears and plums are in blossom flies and humble-bees are too scarce to be of real assistance.

Fruit trees intended to form a permanent plantation do not, of course, come into bearing at once: indeed, early cropping would

be detrimental since it slows down growth, thus rendering the attainment of a full-sized tree an impossibility. Meanwhile, since fruit-soil is usually expensive to rent or purchase, a grower cannot afford to allow the space between his young trees to remain idle, hence it is customary, while the permanent trees are growing, to fill in the unoccupied spaces with vegetables, strawberries, black currants or fruit trees on dwarfing stocks. The greatest care should be taken that none of these crops used for filling in be allowed to remain long enough to interfere with the permanent trees. This caution applies chiefly to the fruit trees used as "fillers": if these are not on dwarfing stocks or, alternatively, of weak and fertile habit (like Fertility pear or Victoria plum), there is a danger that they may only reach the profitable part of their life when they are due for removal.

The actual details of planting, not a formidable operation, are easily obtainable from any reputable text-book.

Cultivations.—An enormous amount of money was formerly spent on keeping the ground clean in fruit plantations by means of hand labour. Post-war conditions and the necessity for mass production have driven growers to dispense, wherever possible, with human muscles and to employ horse or tractor labour. Fruit trees, in their natural state, are not found growing on bare ground: like every other living thing, they have competitors in the battle of life. Weeds, so much hated by the vegetable grower (and with reason), are not as detrimental to the health of fruit trees as was formerly imagined: indeed, it is now realized that a crop of weeds at the right time may have a valuable influence on the colouring, ripening and keeping quality of apples. On the other hand, it must be remembered that during the first five or six years in the life of a plantation every effort should be made to help the trees to grow, and that competitors for food material and water, such as weeds, are not desirable. Intercrops ought, therefore, to be so arranged that cultivation can be carried out as easily and cheaply as possible.

It has been said that in the later life of a plantation weeds in certain circumstances may exercise a beneficial effect on the crop. In order to simplify cultivation, and especially when tractors are used, grass and weeds may be left in the tree rows throughout the year, being cut down only to prevent their seeding. And on certain soils, especially in a wet season, all cultivations may cease in August. In practice this has been found to improve the colour of apples and to check the production of rank, unripened wood.

This practice, which has been proved to be effective, is, nevertheless, contrary to all the canons of fruit growing, and most growers still strive to keep their plantations as clear as possible.

Manuring.—As in the case of other horticultural operations there is no rule of thumb, applicable to all soils and circumstances, for the manuring of fruit trees. A good deal of information concerning local manuring practices is accessible, but these practices are obviously not of universal application. Research has also been

carried out on more or less scientific lines, but so far the results of experiments in the field have been chiefly negative. Nevertheless, general principles are being discovered.

The three chief elements needed by fruit trees are nitrogen, potassium and phosphorus. Nitrogen (*a*) deepens the green colour of the foliage and increases its size ; (*b*) increases the amount of growth made ; (*c*) delays leaf-fall ; (*d*) is necessary for fruit-bud formation ; (*e*) improves the setting of blossoms ; (*f*) increases the size of fruit ; but in excess (*g*) delays ripening, and (*h*) prevents the attainment of high colour.

Phosphorus is considered to be essential for the development of roots and for the formation of blossom-buds ; and unless adequate available potash is present in the soil, extra applications of nitrogen are useless : a " balance " of nitrogen, potassium and phosphorus is needed.

It is supposed that all fruit soils are adequately supplied with phosphorus, though whether this is always available to the trees is not known. Nor is it known whether extra phosphorus is needed when the trees are manured with nitrogen and potash. The general opinion is, that occasional dressings of phosphorus in the form of superphosphate are beneficial.

In the case of potassium it is definitely known that although good fruit-soils contain this element, trees, as they gain age and reach the fruiting stage, begin to suffer from the lack of it ; and there are probably few bearing orchards which would not benefit from the application of at least a hundredweight of sulphate of potash per acre annually.

Large sums of money have been spent on manuring fruit trees but it is not really known whether results have justified this expenditure, moreover, most systems of manuring are not based on scientific data. In certain conditions (as at Woburn) manuring with " artificials," or with dung, or with both, may give no results whatever. Nitrogen is the only chemical which has been definitely shown to affect the character of fruit and dressings of quick acting nitrogenous manures (such as nitrate of soda) generally give marked results in improved growth and cropping when trees are in poor condition or growing in grass orchards.

Obviously, before spending money on manuring, it is desirable to study the behaviour of one's trees. The following points should be noted : (*a*) amount of growth made annually ; (*b*) colour and size of leaves ; (*c*) colour and size of fruit ; (*d*) set of fruit : (*e*) amount of blossom.

Poor annual growth may be an indication of nitrogen starvation or of water shortage. Similarly with yellowish or pale green leaves. Small fruits, very highly coloured, are again usually an indication of lack of nitrogen or of water shortage. Delay in coming into bearing may be the result of too much nitrogen, too much water, or excessive pruning.

To be on the safe side the grower would be wise to insure himself

against trouble by annual dressings of potash and phosphate, and to apply rapidly available nitrogen as soon as he sees any of the danger signs pointed out above.

There is another method of manuring which is likely to be more widely adopted in this country, a method which, in addition to keeping up the fertility of the soil, has also the advantage of increasing its humus content and therefore its water-holding capacity: this is the method of "green manuring." Under this system a crop such as mustard, quick in growth and affording a large bulk of green material, is sown between the rows of trees, allowed to reach a certain stage of growth, and then buried by the plough.

It will be observed that mustard sown in July will perform the same function as a crop of weeds: that is to say, by withdrawing water and food material from the ground it checks the growth of the trees and helps to colour the fruit (in the case of apples); finally, when ploughed in, it becomes itself food for the trees. Naturally, this method must be used with discretion. If soil conditions are such that growth normally slows down in the autumn and fruit colours well, in other words, if the soil is already on the dry side, a heavy crop of water-absorbing plants is not desirable among the trees. In such conditions clean cultivation is preferable, since this helps to prevent evaporation of water from the soil.

Not much information is available as to the practice of green manuring, but a grower by the study of his own conditions will be able to evolve a system for himself which may take the form of mustard or rape for ploughing in during the autumn, or crimson clover for ploughing in in the spring, though these suggestions by no means exhaust the possibilities of green manuring. A leguminous crop, of course, makes a much larger contribution to soil fertility than a *Brassica* crop such as mustard.

Pruning.—In the course of a few paragraphs it would be utterly impossible to describe the whole art of pruning fruit trees. Like every other horticultural operation, pruning cannot be reduced to rule of thumb methods, though many attempts have been made to do this. Trees being living things with individualities of their own, extremely sensitive to soil, water and climatic conditions, clearly cannot be expected to react always in the same way to cultural operations. Once more the grower will find himself, when confronted by trees which he wishes to prune, compelled to call on his reserve stores of common sense, judgment and experience. It is quite easy, by means of faulty methods of pruning, to postpone almost indefinitely all chances of a paying crop of fruit; on the other hand, by no pruning at all, one may obtain with equal ease heavy crops of low-grade fruit at a time when the trees should be giving their best results.

A fruit grower requires from his trees a maximum quantity of high-grade fruit, and in order to achieve this object experience has shown that a tree possessing certain characteristics is necessary. The tree should be so shaped that air and sunlight have free access

to every part of it : a mass of tangled branches shading one another and producing small, uncoloured fruit is clearly not desirable. The branches should be well spaced and well balanced, and the shape of the tree should be such that tillage and spraying operations are facilitated, and that the thinning and harvesting of the crop can be easily and rapidly carried out. The scaffolding or framework of the tree should be strong so that in future years it can resist high winds and support its crop without bending or breaking.

Every variety of fruit tree, if left unpruned, has its own characteristic habit of growth : some are low and spreading, others tall and almost cypress-like. In few cases, however, does their natural habit even approximate to the shape desired by the grower. This desirable shape is that of a rather cup or bowl-shaped tree with an open centre : a shape which no fruit tree adopts of its own accord.

Before passing to the means by which this shape, or a modification of it, is obtained, it is desirable to state a few fundamental principles. In the first place, using non-scientific language, there appears to be a " balance " between the root system and the shoot system of the tree : if this balance is upset the tree hastens to redress it. That is to say, if part of the shoot system is removed fresh shoots are made ; and if part of the root system is removed shoot growth slows down until a balance is attained again. Left unpruned the tree continues until it reaches a bearing age, when it commences to form blossom buds. But if its balance is upset every year by the removal of large quantities of its shoot system, the energies which would normally be directed to blossom formation are diverted into wood production and cropping may be postponed for many years. On the other hand, if its balance is continually upset by the death or removal of parts of its root system, it will almost cease making fresh shoot growths and (providing that the balance is not seriously upset) will rapidly reach the fruiting stage.

The application of this principle of the balance of root and shoot is seen wherever trees are correctly pruned. The case of a young tree intended for a permanent plantation may be considered. Left to itself and when once established this might easily make extension growth at the rate of two or three feet annually, and would in a few years have a framework of wand-like branches many feet in length. But such a framework is useless for commercial work : a short, sturdy scaffolding is required to support the future branch system of the tree. Annually, therefore, branches required for the scaffolding are shortened and the balance between root and shoot is upset. The portion of the branch retained thickens and sends out fresh shoots to redress the balance ; selected shoots are again shortened, and ultimately a sturdy framework for the future tree is obtained.

Similarly with the operation known as spur-pruning, which is carried out on what is known as the fruiting branches (as distinct from the framework) of apple trees. On a shoot of an apple tree blossom buds are usually to be seen towards the distal portion of

two or three year old wood. This fruiting often only begins where the branch has reached an unwieldy length : an effort is made, therefore, to obtain blossom buds on shorter, sturdier shoots. Side branches on the framework are shortened and their energy concentrated on, say, four or five buds only. In the following year, instead of a long, thin shoot, we have a short one with two or three side branches ; these are in turn shortened and in course of time blossom buds may be found developing on the lower (proximal) portions of the shortened shoots. When this occurs the branch is shortened to a blossom bud.

A warning must be issued concerning spur-pruning. Obviously, if the tree is young, has not reached a bearing age, and is growing vigorously, the result of shortening a branch is to produce more wood. And if this wood is in turn shortened, more wood is again produced ; and this process may continue, without the formation of a blossom bud, for very many years. The writer has, in fact, examined spurs on strong-growing apples which had been cut back annually for twelve years and were still producing nothing but infertile shoots. Obviously, then, vigour of variety, stock, and soil and water conditions must be taken into account in evolving a method of pruning.

Another important point which it would be fatal to neglect is that of the reaction of different varieties to the mutilations of the pruner. Shortening a leading shoot of a young tree of Allington Pippin to half its length may result in causing every bud below the cut to produce a shoot the following year ; whereas in the case of Lord Derby probably only three of the buds below the cut would give shoots. Thus careless pruning of Allington Pippin might, in some circumstances, have the result of choking up the tree with a forest of useless, sappy wood, and it would have been far better to have left the tree alone since, if left to itself, Allington rapidly covers itself with fertile wood.

Certain varieties of apple produce the greater part of their flowers on the tips of young shoots ; shortening these shoots would therefore have the result of depriving the tree of its crop. A variety which shows this character in an extreme form is Worcester Pearmain. Pears usually show this habit of fruiting, but in addition produce many lateral fruit buds and are, as a rule, easily reconciled to spur-pruning.

The pruning of plums differs from that of apples and pears. The preliminary scaffolding required must be strong, as with apples, but no spur-pruning is practised. Plums usually begin to bear fruit long before their branches are strong enough to support a crop, moreover they are thin-wooded as compared with apples, hence to counteract the inevitable tendency to droop caused by precocious fruiting, a certain amount of shortening (" tipping ") of the leading shoots will be needed if bush plums are grown. Standard and half-standard plums are, however, mostly planted, and after these have had their preliminary shaping little pruning beyond the excision of

superfluous branches is done. In any case, owing to the prevalence of Silver-Leaf disease in this country and to the fact that two of our most popular commercial plums (Victoria and Czar) are extremely susceptible to its attack, as little pruning as possible should be done during the period when the spores of this fungus are liable to germinate on the cut surfaces of branches, that is to say, during autumn and early winter.

So far only the winter pruning of fruit trees has been considered. In commercial plantations where dessert apples of high quality are grown, a form of pruning is carried out in late summer or early autumn with the object of admitting light and air to the fruit and of thus improving its colour. Summer pruning, with this object in view, is usually only necessary with closely spur-pruned trees, and consists of shortening all young wood not needed for extension of the framework to a length of about six inches or less.

On standard and half-standard apples no pruning beyond the thinning out of surplus wood is done once the framework of the tree has been laid down.

Spraying.—Under modern conditions it may be possible to cut down expenses of cultivation and even of manuring, but to attempt to economize on spraying would be a disastrous policy. Nowadays success depends on the production of clean, unblemished fruit, properly graded and packed, and without spraying it is not possible to produce fruit of the highest quality.

Fruit trees are attacked by both insects and fungi. Insects injure the tree by devouring its leaves, buds, fruit and blossoms, or by sucking the juices from leaves and fruit. And to make matters worse they may act as carriers of virus diseases such as "mosaic" of raspberries and "reversion" of black currants.

The principal pests of fruit trees are (*a*) Aphids; (*b*) Caterpillars (the larvæ of various species of moths); (*c*) Capsid Bugs; (*d*) Apple Sucker; (*e*) Apple Blossom Weevil; (*f*) Apple Sawfly; (*g*) Pear Midge; (*h*) Red Spiders.

In order to gain control over these pests (actual elimination is not possible) and to prevent their ruining foliage and fruit, the chief method is that of spraying the trees with liquid preparations designed: (*a*) to kill during the winter eggs which have been deposited on the bark of the tree; (*b*) to poison the insects themselves through their spiracles or breathing pores; or (*c*) to kill them by coating with a layer of poison the leaves on which they feed. For killing eggs "tar-oil washes" are used. These destroy the eggs of both moths and aphids. Before their advent the control of aphids on plum and damsons was always a matter of great difficulty, since these insects are able to protect themselves by curling the leaves on which they are feeding.

Insects which obtain their food by puncturing the tissues of their host plant and sucking its juices are killed by "contact washes," and of these the most important is nicotine. Insects of this type are Aphids, Apple Suckers, and Capsid Bugs. (Both

Aphids and Apple Suckers can also be attacked in the egg stage by tar-oil washes.)

Such caterpillars as are not dealt with by tar-oil spraying are killed by internal poisoning. Caterpillars, of course, do not puncture the tissues of plants but gnaw them, hence if the leaves are coated with poison this poison is actually eaten by the insect. The principal internal poison used for this purpose is arsenate of lead.

Contact washes should be applied with force and through a coarse nozzle, whereas arsenate of lead is applied as a fine mist in order to cover the foliage of the trees with a very thin layer of the poison.

Certain pests cannot be attacked on the lines given above: among them are the Pear Midge and the Apple Blossom Weevil. At present no method of controlling Pear Midge is known and the damage it does (often very serious) must be endured. The Apple Blossom Weevil lays its eggs in the flower buds of the apple. Infected flowers do not open but become hard and brown, thus protecting the larvæ which feed within secure from contact and internal poisons alike. The mature insects can, however, be trapped in sacking or corrugated paper tied round the stem of the tree.

The literature of spraying is quite extensive, a beginner will therefore have no difficulty in obtaining reliable information concerning the technique of pest control.

Unfortunately, in addition to being attacked by pests, fruit trees are subject to diseases, most of which are caused by fungi. The most serious of these are Black Scab (of apples), Pear Scab, Silver-Leaf (of plums and apples), Apple Canker, Apple Mildew, Brown Rot and Blossom Wilt. Of these Black Scab and Silver-Leaf are probably the fruit grower's worst enemies. Scab is controllable, but unfortunately, little can be done to check the damage done by the Silver Leaf fungus.

If clean fruit is desired a programme of anti-scab operations is absolutely necessary for, in addition to attacking the young wood and leaves, scab injures the fruit and renders it either unsaleable or of very low grade. Bordeaux mixture, lime sulphur and colloidal sulphur are used in fighting this fungus. Care is needed in the use of Bordeaux and lime sulphur since they may seriously damage the foliage of some varieties of apples, or actually defoliate the trees if used at the wrong time or at too great a strength. Scab can, however, be kept in control by spraying, and although more information on the subjects of scab control and spray damage is needed, there is sufficient information available to enable a careful grower to produce at any rate a high percentage of scab-free fruit.

Where Silver-Leaf is prevalent little can be done save cutting out infected branches and burning all dead wood. This fungus only produces spores after the death of its host. Unfortunately, it can thrive on many hard-wooded trees and has even been seen fructifying on a gate-post, hence its control is often difficult of achievement. It chiefly attacks plums, but when trees are healthy

and growing and behaving normally it is less likely to be found than in districts where trees, for various reasons, are not in perfect health. For instance, when Victoria plum is grown on myrobalan stock the incidence of Silver-Leaf is high, and if it is grown on this stock in conditions which tend to produce excessive sappy growth the incidence is even higher.

It should be realized that while it is possible to keep under control most of the diseases caused by fungi, it is not possible to get rid of them altogether; constant watchfulness is needed, and a well thought out programme of spraying. The grower obviously ought to have some knowledge of entomology and mycology, otherwise he may find himself wasting money on sprays applied at the wrong time, or applied in the wrong manner. Or he may even waste money on unnecessary spraying.

A recent development of the technique of pest and disease control is that of "dusting," *i.e.*, the application of insecticides and fungicides in the form of dusts instead of as liquids. Dusts have many advantages over liquid sprays, and the chief of these are the speed at which the operation of dusting can be carried out and the very great saving in labour and appliances. American and Canadian growers use dusts on an extensive scale, and it is probable that in the near future their use will pass beyond the tentative stage in this country.

Marketing.—Having surmounted the problems involved in the growing of a good sample of fruit, the grower's difficulties are by no means at an end: he has (*a*) to present his produce in a manner which will attract salesmen, retailers and the public; and (*b*) to ensure that it reaches the market which will give him the best return for his labours. These two problems of presentation and disposal are not of equal difficulty. At this time of day there can be no question as to the necessity for presenting high-class produce in guaranteed sizes and quantities, packed in standard containers. Foreigners and colonials at one time captured our markets not by virtue of the superior quality of their fruit but because they sent us material standardized in quality and quantity and were, in addition, able to keep up a continuous supply of it. Thus the salesmen, merchants and retailers could, to a large extent, regard fruit as they regarded flour or soap: they had to deal with packages of standard size containing fruit of known quality, moreover, when their supply was exhausted they knew that more packages of the same kind were available. Under modern conditions, this state of affairs is not only desirable but essential. And the old-style English grower, with his fruit of all sizes and qualities jumbled anyhow in whatever types of container struck his fancy, found himself edged off the markets or compelled to accept the lowest possible prices. It is only necessary to look in a greengrocer's window to see that this state of affairs is in existence even now, after years of propaganda and effort on the part of both Government officials and private individuals: there are the familiar Jonathans or Winesaps,

even in size and quality, and selling at sixpence or eightpence a pound, while in a corner of the shop may probably be seen a decrepit hamper filled with apples of all shapes, sizes and qualities, labelled "English, twopence a pound."

Fortunately, less and less of this low grade English fruit is to be seen year by year, and at the present time all up-to-date growers are familiar with the technique of grading, sizing and packing. It is therefore unnecessary to insist here on this aspect of marketing.

The question of selling fruit to the best advantage is one of greater difficulty. It is possible to hire a skilled foreman who will carry out satisfactorily all operations up to the packing of the fruit, but disposing of this fruit is another matter. As a rule, growers detest the business side of fruit-growing, but obviously it is on this that success chiefly depends; therefore too much attention cannot be given to it.

When a grower sells his own produce locally, either direct or through retailers, the problem is simplified; but when he wishes to dispose of it in distant markets (as he must do if he produces fruit in bulk), numerous difficulties arise. And so long as growers prefer individual effort to co-operative marketing these difficulties will persist.

A step in the right direction has been made in the United States, where growers send their fruit to co-operative selling agencies; here it is graded, packed and sold. In other words, a move in the direction of specialization has been made: the grower, instead of attempting to carry out every operation, confines himself to the culture of fruit, handing over to specialists the task of packing and distributing. This is the modern tendency, unfortunately inescapable, and it is to be seen throughout the industrial world.

Among the more important problems to be faced by growers is that of transport. It is clear that here individualism cannot pay so well as co-operation. Small lots are charged maximum freightage, each lot has to bear its own separate cost of transport to and from the railway, and each lot has to be handled separately by salesmen. Individualism here is clearly an expensive luxury.

On the other hand, a large grower is more favourably situated: he is in a position to send a regular stream of standardized products comparable to that emanating from some large factory.

The selection of markets, or outlets for produce, is not an easy task, and many growers are content to send off their fruit largely as a speculation. A knowledge of the conditions pertaining to the various markets available is often only gained after long, and perhaps, painful experience. Careful study of marketing is therefore essential to success.

Since the grower, once he has despatched his fruit, is literally in the hands of the salesman who acts as intermediary between him and the retailer or selling agency, every effort should be made to discover a reliable salesman in each market. Once he is discovered,

it is well to realize that he is, before everything else, a business man ; he wants the best produce, a regular supply of it, and he wants it well packed and as far as possible standardized. Only when these conditions are fulfilled is he able to keep up his connections with retailers and make a good profit for himself and his grower.

Only a few general principles can be mentioned here ; but much information on the subject of marketing is now available to growers and the marketing of fruit need no longer be the somewhat haphazard affair that once it was.

Soft Fruit.—Strawberries, black currants and raspberries are at present the most popular soft fruits. While plantations of top fruit are maturing it is desirable that the ground should be giving some return, and this return is usually obtained from soft fruits, except in districts where flowers and vegetables are more profitable. Soft fruits are also grown alone, and this is especially the case with strawberries.

The three kinds of soft fruit named are found growing wild in the North Temperate zone, in cool, moist conditions. This fact should give some indication of the conditions necessary for success. Obviously, bare, baked hillsides or dry, sandy soils are not situations where one would expect to find these plants thriving, and it is possible that many of the failures to cultivate them successfully are due to disregard of their soil and water requirements.

Strawberries are in demand throughout the year, either as fresh fruit, or as jam, or in cans. They are suitable for the small grower with a local market and for the large grower who may despatch his fruit to markets a hundred miles or more away.

As in the case of other fruits, bulk production of strawberries has tended to be confined to definite areas, both soil and climate having influenced these segregations. If climate is favourable, that is to say, if there is a reasonable chance of safety from late frosts when the plant is in flower, and, better still, if there is a possibility of producing crops early in the season when prices are high, soil can be to some extent neglected, for it will pay to make some effort to render the land suitable for this crop. Strawberries are, for instance, grown profitably in Hampshire on land which would normally be moorland. Earliness is here the important factor.

The list of strawberries grown for market purposes in this country is not a long one ; in fact, two varieties only—both old ones—take precedence of all the rest. These are Royal Sovereign and Sir Joseph Paxton. So far, in spite of numerous introductions of new varieties, these two have retained their hold on the affections of growers, salesmen and retailers. Other varieties on trial (but unlikely to supplant Sovereign or Paxton) are Madame Lefebvre, Deutsch Evern, Oberschlesien (the most promising) and Tardive de Leopold.

Brightness of colour, firmness of flesh, ability to travel well, productivity, are important points in the make-up of a commercial strawberry. And of these, softness of flesh has been a defect in

many otherwise good introductions which has led to their relegation to the private garden.

It must be realized that although Sovereign and Paxton are pre-eminent on the market, they will not show their best in every district, and before planting up a large acreage it would be advisable for the grower to lay down a trial plantation of varieties, including those specially suitable for jam-making and canning.

Black Currants.—Of recent years, since England has become the target for fruit growers all over the world, heavy importations of black currants have depressed the value of this once very profitable crop. Although prices will probably not rise again to the high level reached after the war, this crop should not be neglected by growers, especially as neither its culture nor its marketing present very formidable problems.

Bud-mite, " reversion," " running-off," have all contributed to deter growers from planting black currants. Much research has been carried out on all these problems, however, and with the information now available black currant culture does not present the serious difficulties which at one time resulted in the premature grubbing up of many plantations.

The effective control of bud-mite by spraying with lime sulphur is a simple affair ; and where bud-mite and aphis are controlled the virus disease known as " reversion " becomes a less serious menace.

The chief varieties grown in this country are Seabrook's Black, Baldwin, Boskoop Giant, Goliath and Edina. If only one variety is planted this should be Seabrook's Black, which shows a certain amount of resistance both to bud-mite and to reversion, and in addition, has been thoroughly tested on a commercial scale in Eastern England. For the West, and where conditions are wetter, Baldwin, a very heavy-cropping variety of rather weak growth, is profitable.

It should be emphasized that unless care is taken to control the attacks of bud-mite, aphis and caterpillars, and to destroy reverted bushes as soon as they are discovered, the culture of black currants is not worth attempting.

Raspberries.—This is another crop suitable either for small or large scale production. As in the case of other fruits, the exigencies of commercial conditions have resulted in the cutting down of the number of varieties grown. At the present moment the following are chiefly planted :—Lloyd George, Red Cross and Pynes Royal. If one variety only is to be planted, Lloyd George should be the one chosen. A grower might, however (as with other fruits), make a preliminary test of varieties to suit his special conditions.

Provided he is on a reasonably good fruit soil, the grower will find that the culture of raspberries presents no great difficulty, if he will avail himself of the results of research on the manuring of this crop and on its pests and diseases.

Raspberries are not so profitable to grow as once they were, and before planting them the grower would be wise to study market

conditions. The events of recent years have shown that in a very short time a crop from being extremely profitable may change in value and be hardly worth growing. At the present moment few men would care to launch out on extensive plantings of black currants, raspberries or gooseberries. On the other hand, early cooking apples, Bramley's Seedling, Worcester Pearmain and strawberries still appear to be safe propositions.

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MARKET GARDENING.

In the normal course of events the methods adopted by market gardeners in producing their crops would have little interest for a farmer : indeed, the sight of a vegetable grower "poisoning" his land with 40 loads of dung and half a ton or more of artificials to the acre has often in the past been food for mirth rather than for respectful interest. However, times have changed and many farmers are now greatly interested in horticultural crops ; and the fact that in September, 1931, three bags of Brussels sprouts fetched more money than a sack of wheat has no doubt tended to make them even more interested than before.

Of course, the insertion of a market garden crop in a farm rotation is no new thing : when conditions are suitable cabbages, sprouts or peas have often been found worth while attempting. But it is now realized that a greater attention to market garden crops may help to solve the perennial problem of how to make farming pay. At least, it may do so for those farmers who are on land suitable for market garden work and in districts where the more profitable crops such as broccoli or cauliflowers can be grown.

Market gardening, or the growing of horticultural crops, is not to be embarked upon lightly. It is true that on paper the returns from vegetable growing are extraordinarily stimulating. For instance, cauliflowers and broccoli may be worth £95 per acre, but that is not the whole story for there is cost of production, to say nothing of skill and experience, to be considered. Cost of production may easily amount to £40 per acre ; and the technique of growing horticultural crops well and marketing them successfully takes a long time to acquire.

For a farmer, however, the step from purely agricultural to purely

horticultural crops need not be a very formidable one: though it will, of course, be formidable if he is thinking of cultivating such crops as forced sea-kale, or tomatoes and cucumbers under glass. But to change from cereals and roots to Brassica crops and onions is fairly easy, at least as far as mere production is concerned: it is when the question of marketing arises that trouble begins. At the same time, one must emphasize the fact that even when conditions of soil, moisture, and climate are favourable for vegetable growing, a mere agricultural scratching of the soil to a depth of four or five inches, plus a few loads of dung and a hundredweight or so of fertilizers, is not enough for horticultural crops. Deep cultivation and heavy manuring are necessary for the growing of profitable market garden produce. The old-time Middlesex grower brought back a load of London dung for every load of produce sent to Covent Garden. The French maraichère, so it is said, takes his top soil with him when he moves to a fresh site, for this top soil has been built up with hundreds of tons of valuable stable manure. Fifty tons of manure to the acre was once considered to be quite an ordinary dressing for certain crops, and even now many a man would use this amount if he could get hold of it at a reasonable rate. The truck farmer (*i.e.*, specialist large scale vegetable grower) of North America may apply a ton or more of a high-grade mixed fertilizer to the acre.

It is obvious that here is a state of affairs very different from that encountered in ordinary farming and the layman may wonder if all this expenditure in manuring is not over-done. Experience proves the contrary. The market gardener is almost solely concerned with the vegetative parts of his plants; if seed were the edible part of the onion plant it could be produced at small expense, but to force the plants to produce the mass of swollen leaf-bases which forms the onion bulb is a difficult and expensive matter. And there is the question of quality of produce to be considered; the grower who aims at a large bulk of low-grade vegetables is liable to find himself in difficulties when markets are over-loaded and retailers can pick and choose, whereas the man who has concentrated on quality scores. Quality, in the case of vegetables, is not obtained without much expenditure on cultivating and manuring.

As for marketing, unless a local sale is assured, a knowledge of markets and of marketing conditions is essential for success. In years when growers of, say, Brussels sprouts can be heard complaining that their consignments have brought in no cash return worth mentioning, one can always find men who, by attention to packing, grading, and quality, and through a knowledge of the markets, contrive to sell their produce at a profit.

In short, the growing of vegetables for market will involve, for many farmers, a radical change in cultural methods, a much increased expenditure in cultivations and manuring, and a close study of marketing conditions. The returns from horticultural crops are as a rule much higher than those obtained from ordinary

farm crops ; but they are not obtained without extra capital and extra effort.

It is also necessary to add that the production of vegetables is already being carried out on a large scale in this country. The case of vegetables is not parallel with that of fruit : we import enormous quantities of fruit, but most of our vegetables are grown at home. There is, therefore, always the bogey of over-production lurking round the corner. Transport facilities are not by any means as good as they might be in this country, and therefore the transference of material from the place of production to the place where it is needed is badly hampered. A further hindrance is the policy of retailers who almost everywhere would rather sell a small quantity of vegetables at a high price than a large quantity at a low one. In view of the perishable nature of vegetables and difficulties of transport, this policy can be easily understood ; but it undoubtedly leads to the waste of much valuable produce that ought to be available to the poorer sections of the community.

The vegetable grower, then, should be a business man, on the look-out for an opportunity to go one better than his neighbour. He can do this by growing better produce, by better packing and grading, and by being alert in the exploitation of special lines which he may discover are profitable to grow in his district. There is no doubt that a state of affairs has been reached when, as in the case of fruit, it rarely pays to grow anything but the best. Vegetables are not regarded by the public in the same way as bread or meat : they still remain to a large extent in the category of luxuries. There is much capriciousness in the public taste : one year summer cabbages are unsaleable and have to be ploughed in : the next year they may fetch good prices. A market gardener is not supplying the public with goods which they must have : he is merely supplying them with luxuries which they will buy if they can afford them and if they are sufficiently tempted by them.

Soil and Climate.—Of these two factors climate is probably the more important to a market gardener. The soil round Penzance is not one that a gardener would prefer to all others, but the climate of Penzance is such that the valuable Roscoff type of broccoli (or winter cauliflower) can be grown with little fear of frost damage and sent to market three months before ordinary types are ready to cut in colder parts of the country. Earliness on the market means extra money : early cabbages, early cauliflowers, early Brussels sprouts are all valuable. When the whole country is producing cabbages, the price drops. A grower should therefore pay careful attention to this question of climate. Unless he has his own local outlet, it is not desirable, and may not be profitable, for him to be sending his consignments of spring cabbages to market after the cream has been skimmed off by the men in early districts who were in a position to send weeks ahead of him. The public soon becomes surfeited with any one kind of vegetable and transfers its attention to another.

As a general rule cold districts or districts having a "continental" type of climate (hard winter and dry summer) are not suitable for the commercial production of such crops as spring cabbage, Brussels sprouts or early (autumn-sown) peas. There are enough difficulties to contend with already, without adding to them a struggle with unsuitable climatic conditions.

Nor are dry districts desirable. In growing vegetables the limiting factor is usually water. Abroad—chiefly in America—irrigation is extensively practised. It could be practised here, too, with advantage, particularly with such crops as lettuce, cauliflower and celery, where quick unchecked growth is necessary if high quality produce is desired.

Although all the more important vegetables appreciate plentiful and regular supplies of water, a water-logged soil is fatal to success. The root range of vegetables is surprisingly large and if root growth is checked by water logging stunted and unprofitable plants are the result.

It would be dangerous to dogmatize on the question of soil for, as it has been pointed out, the factor of climate may dictate the position of a vegetable growing area. Vegetables are to be seen growing on diverse types of soil, from sands and silts to boulder clays and black peat soils. Even in these days of improved transport, market gardening is usually to be seen carried out in the proximity of large towns, on whatever soil they are situated. Here the opportunity of engaging in a local trade outweighs possible unsuitability of soil.

Nevertheless, it is possible to mention qualities that are desirable in a soil on which vegetables are to be grown. It should, of course, be easily worked: workable in winter and after rain. With parsnips, Brussels sprouts and lettuce one cannot wait until alternations of frost, dry weather and rain have rendered soil sufficiently manageable for seed-beds to be made. The best soils, those most cheaply and effectively managed, are therefore on the light side. And they are deep. Vegetables repay deep cultivation. The private gardener who exhibits onions weighing a couple of pounds each, giant pods of peas, or incredible celery, as often as not trenches his ground to a depth of three feet. Trenching is not practicable on a commercial scale. On the other hand, soils which are penetrable by roots to a depth of three feet are to be found and are desirable. Three feet of stiff clay is no use to a market grower but three feet of sand or black peaty soil may mean money to him.

A good vegetable soil, being light, is well aerated. Aeration encourages root production and without large root systems vegetables cannot give the best results.

The soil should be well drained. Stagnant water about their roots spells disaster to horticultural crops.

When stable manure was cheap and easily obtained vegetable growing was possible on drier sandy soils. An instance of this is the area near Sandy, in Bedfordshire, situated on the Lower

Green-sand. Normally these soils, unless the underlying impermeable Gault clay is near enough the surface to hold up a supply of water, are only suitable for heath plants; but by the addition of heavy dressings of manure and the accumulation of humus they become more retentive of water and therefore suitable for vegetable growing. A sandy soil is, too, earlier than a clay: it warms up more quickly in spring.

On heavier soils, provided they are well drained and deeply worked, Brussels sprouts, cabbages and cauliflowers will succeed. But a market gardener does not like to keep his ground idle: he wants crop to follow crop rapidly and may even have two crops on the ground at the same time, one maturing, the other commencing growth. Heavy, intractable soils are therefore of no use to him. On the other hand, a farmer who occasionally fits in a Brassica crop and thus has plenty of opportunity to get his soil into the right condition is not deterred by a certain amount of heaviness.

To sum up: a vegetable soil should be deep, well drained and easily and cheaply worked. It should be in a district of fairly high rainfall and in a climate that favours the growing of such plants as are in the ground all the winter. These are ideal conditions and are mostly found in the south, south-west and west of England. Proximity to the sea is a valuable asset to the grower of broccoli or cauliflower, though if he is on the east coast spells of biting east or north-east winds may ruin his crops. But it is clear that vegetables can be grown successfully on many soils and in many situations. Celery is grown on a large scale in the black fen soils of Cambridgeshire; cabbages are grown on the silts of Lincolnshire. A market gardener—a man who grows a large variety of vegetable crops—needs special soil and situation; but the English equivalent of the American "truck-farmer," who specializes in a few crops grown on a very large scale, is not necessarily so limited as regards climate: his crops may be all off the ground by the time winter sets in.

It is therefore unsafe to dogmatize on the questions of soil and climate, though one may say definitely that cold, wet districts and heavy, undrained soils are undesirable for the commercial production of vegetables on a large scale.

Manuring.—It is necessary to realize that in the question of crop manuring actual experiment by the grower himself is the only guide. A multiplicity of "manurial experiments" has been carried out for the benefit of farmers and horticulturists, but until recent years they have for the most part been statistically unsound; and even when a manurial experiment is sound statistically its results can only apply to the piece of ground in which it was carried out and to a particular season. Fundamental research is badly needed.

Soil analyses are of little use to the grower. A sack of sawdust has locked up in it valuable food material but the human digestive system cannot make use of it. Similarly with soils: they may contain all the elements for plant growth but plants may not be able to get at them, or may only be able to obtain them in such small

quantities that, as far as vegetable growing is concerned, they are of very little help. Hence it is universally conceded that if good vegetables are to be grown they must be well fed. And no matter how well they are fed they cannot show their best unless they are amply supplied with water.

It is probable that, since most commercial vegetable culture is carried out on lightish soils, the function of very heavy dressings of stable manure has been chiefly to increase the water-holding capacity of the soil. Therefore it is possible, provided water conditions are right, or if irrigation is practised, to cut down manuring for humus production and to rely to a greater extent on fertilizers. But whether obtained from dung or from manuring there is no doubt that humus is absolutely necessary to the vegetable grower if he is on a light soil in a district of low rainfall. A market gardener practising intensive culture and aiming at high quality would probably find—as certain growers have already found—that overhead irrigation as practised in America would pay. But for mass production of the cruder crops such as sprouts or celery it is ruled out, though there is no doubt that ordinary furrow irrigation would be of inestimable value to many growers in this country.

The list of elements, or raw food materials, needed by vegetables to enable them to live and grow is a formidable one. It includes nitrogen, potassium, phosphorus, iron, sulphur, magnesium, calcium, carbon, hydrogen, oxygen. Recent research has shown that traces of manganese, boron, copper and zinc may also be needed. Fortunately a grower need only concern himself with three of them: nitrogen, potassium and phosphorus. The plant obtains its hydrogen and oxygen from water and its carbon from carbon dioxide present in the air; as for the remaining elements, they are supposed to be present in sufficiently large quantities in the water absorbed by its roots. In America it is stated that good results have been obtained from dressings of manganese sulphate. The practical man over here concentrates his efforts on supplying his plants with those elements of which they need large quantities—larger quantities than can be supplied by the average soil.

It would be no good recommending here definite manurial treatment: the kind and amount of fertilizers required must clearly depend on the nature of soil, climate and crop. In a vegetable-growing area there is the result of the accumulated experience of generations of growers to be drawn upon, and the beginner will be wise if he avails himself of it.

Nitrogen is necessary for the full development of the vegetative portion of a plant and is therefore of great importance in the culture of such crops as spinach, cabbage, lettuce and celery. In growing vegetables the lack of it is more likely to prove a limiting factor than lack of potassium or phosphorus. It is available to the grower in many forms, some of which can be utilized almost at once by the plant whereas others act more slowly. The grower may want his nitrogen to act quickly if for some reason his plants have received

a check or are standing still. For this purpose nitrate of soda or nitrate of lime may be used as a top dressing, but their effect is transitory and unless water and reserve stores of food material are available in the soil the crop will stand still once more after forging ahead for ten days or so. Sulphate of ammonia is used for a similar purpose but acts more slowly.

Growers of Brassica crops find soot to be a valuable fairly slow-acting manure and prefer heavy dressings of it to the more fugitive inorganic fertilizers that have been mentioned.

Probably an ideal state of affairs would be to manure in such a way that the use of tonics such as nitrate of soda was unnecessary : that is to say, by the use of slow-acting organic manures such as stable manure, hoof and horn, meat meal or malt dust. In certain cases this is not practicable. In order to catch the early market it is necessary that cabbages should grow away succulently and rapidly early in spring. But in the early part of the year the ground is not warm enough to stimulate into activity the soil organisms which render the nitrogen in organic manures available to the plant. Available nitrogen must therefore be supplied in the form of soluble inorganic compounds such as nitrate of soda. This is the principal function of these inorganic compounds : to supply rapidly available nitrogen at a time when soil organisms are unable to work at full pressure and thus to keep plants moving and avoid checks to growth.

Phosphorus must be supplied to all market garden crops. It is present in most soils but is not necessarily available to plants. While nitrogen exercises its chief influence in the vegetative parts of a plant, phosphorus is supposed to be concerned in the development of fruits and seeds, and of the fibrous portion of the root system. In market garden practice phosphorus is applied in the form of "superphosphate."

Potassium is said to be essential to starch and sugar formation and is therefore of particular importance in such crops as onions, parsnips, potatoes and carrots. Manuring with potash cannot be avoided by the vegetable grower, for although nitrogen increases the actual area of the leaves of a plant it does not increase their efficiency as food manufacturing organs. Potassium increases their efficiency, however ; therefore, heavy applications of nitrogen are useless unless adequate potash is also present. Similarly, potassium and nitrogen are not fully effective unless adequate phosphorus is available.

Potassium is applied in the form of the sulphate or chloride (muriate). It is usually applied in insufficient quantities by inexperienced growers : on certain soils half a ton to the acre of muriate is found to be not too heavy a dressing for a Brassica crop.

Potassium is also present in wood ashes and these should never be wasted. Kainit is used by some growers ; this fertilizer must be applied well in advance of cropping and is usually put on in the autumn. It contains common salt and is therefore supposed to be

beneficial to plants of which the ancestral forms were indigenous on our sea coasts: the wild cabbage and beet being cases in point.

Lime is of the utmost importance to a vegetable grower. It is known that an acid soil is favourable to the growth of the organism responsible for club root (or finger and toe) in Brassica crops and unfavourable to the activities of the organisms which break down organic manures. A stage is sometimes reached in private gardens manured annually and heavily with dung when further applications of manure have no effect and the fertility of the soil declines : the soil has, in common language, become "sour." Heavy dressings of lime restore its fertility and enable the nitrifying organisms to resume their activities.

Lime has also effects on the texture of soil, more important to the agriculturist than to the market gardener who, if he is wise, chooses in the first instance a soil which requires no amelioration in texture. It renders clay soils more workable and permeable to water, and improves the water-holding capacity of sandy soils.

American experimenters have found that some market garden crops will "tolerate" a certain amount of acidity in the soil ; such are radishes, tomatoes, turnips and Brussels sprouts. But radishes and turnips and sprouts would in this country almost certainly be attacked by club root in a sour soil.

On the whole, it may be said that no vegetable grower can afford to dispense with the use of lime.

A plentiful supply of humus is necessary for vegetable growing, and with the increasing scarcity of stable manure this problem of adding humus to the soil becomes more and more difficult of solution. Continuous application of chemical fertilizers can only be fully effective if the humus content of the soil is preserved and one way of doing this, when stable manure is not obtainable, is by "green manuring." Green manure crops are grown solely for the purpose of soil improvement and are, of course, ploughed in and left to decompose. It will be realized that when land is expensive and intensive cropping has to be practised, green manuring is not regarded as a possibility. But where large scale market gardening is carried on, as in America, green manure crops often form the only source of humus available to the grower. In this country green manuring is not fully exploited as a means of improving soil conditions, though it is practised in some districts in connection with early potato growing.

Green manuring increases the amount of organic material in the soil, transfers mineral food from subsoil to surface, increases the amount of available plant food in the soil, adds nitrogen to the soil (especially when leguminous plants are used as green manure), and prevents the loss of soluble nitrates. To the vegetable grower the most important result of green manuring is that the water-holding capacity of the soil is increased.

In this climate the crops suitable for green manuring are not numerous. Rye and mustard are probably the most popular

short-term crops, but when market garden crops are worked in with ordinary farm rotations it is possible to make use of a long ley (clover and grass), or of red clover alone.

It may be thought that undue emphasis has been laid on the question of manuring vegetables; the writer's experience, however, is that newcomers to market gardening are apt to expect maximum results from a minimum expenditure and that their ideas of manuring are generally inadequate.

Kinds and Varieties.—Whilst some market gardeners, working intensively, grow most kinds of commercial vegetable crops it can be said definitely that not all kinds are suitable for large scale work. Broccoli, cauliflowers, cabbages (white and Savoy), canning and main crop peas, Brussels sprouts, beans, carrots, parsnips and onions are suitable for large acreages, but there are vegetables which either because of special cultural requirements or limited demand are confined to market gardens. Such are usually asparagus, spinach, sea-kale, artichokes, celeriac, salsify, mint, leeks, lettuce, radishes and turnips. Rhubarb (forced), sea-kale, celery, celeriac and salsify are generally in the hands of specialist growers.

As shown by the latest returns issued by the Ministry of Agriculture and Fisheries (for 1930) the acreages of the more important crops in England and Wales were as follows :—

Green peas	56,000 acres	Carrots	9,100 acres
Cabbages	30,800 ,,	Rhubarb	7,700 ,,
Brussels sprouts ...	26,500 ,,	Celery	6,400 ,,
Cauliflower and broccoli	14,900 ,,	Onions	2,000 ,,
Green beans	13,500 ,,		

At the present time there appears to be room on the markets for further supplies of canning peas, Brussels sprouts (high quality produce only), cauliflowers, broccoli, celery (including varieties for canning) and onions (including pickling varieties). Parsnips usually command a sale, especially of recent years owing to the ravages of "canker" and consequent reduction of the crop. There is an increasing demand for spinach and for early and very late Savoys. Lettuces and radishes are also safe crops to grow.

The prospective grower of vegetables should take note of the rapid rise of the canning industry. In the future it is probable that there will be few vegetables which are not canned. There is also an opening for vegetables for pickling, such as cauliflower, red cabbage, onions and gherkins.

No man in his right senses, however, would venture to deal out advice on the subject of what to grow. The most that can be done is to point out lines that appear to be reasonably safe at a particular time. Taking the case of Brussels sprouts, for instance : it is quite conceivable that if many more farmers take up the culture of this vegetable there will be over-production. Though even then there will still be room for the grower of high-class graded produce.

A very important question is that of varieties. The greatest care should be taken in buying seed ; after all, cost of seed is probably

the smallest item of expense in growing a crop. Many growers will object to paying a sovereign for a pound of Brussels sprout seed, considering that four shillings or so is a high enough price. They lose sight of the fact that no " variety " of Brussels sprouts is a variety in the true sense of the word, but merely a collection of varieties ; and that this collection is only kept up to standard by careful selection of parent plants. Cheap seed cannot have been obtained from carefully selected plants, hence if four out of every five plants it produces are " rogues " or " blowers " no surprise need be felt. But rogues and blowers occupy just as much space and require as much labour and feeding as good plants ; they bring in no return and may easily render a crop unprofitable.

Even when a decision has been made as to the kinds of vegetables he is going to cultivate, the grower has still to discover the variety which will suit his land and his market. At the present time he cannot escape the necessity for testing on his own ground different strains of the same variety ; and he may even be driven to attempt to save seed for himself. Seed growing is, of course, a task for specialists. But if the requisite isolation can be secured and if the plants to be used as parents are carefully selected, a grower may at any rate be able to maintain his own stock of a vegetable, even if he does not succeed in improving it. The mistakes commonly made are (*a*) growing parent plants in positions where they are likely to be crossed by plants of other stocks growing in neighbouring gardens (for instance, cabbages cross freely with Brussels sprouts, broccoli and kohl-rabi) ; (*b*) utilizing for seed-parents plants which are not of the highest quality. Growers have been observed to leave for seed a block of inferior broccoli (not good enough to send to market) in a corner of a field : this sort of thing is bound to result in failure.

A clear idea of the required type of vegetable must be kept in mind and only the best specimens of this type should be used for breeding purposes.

Pests and Diseases.—Much work remains to be done before mycologists and entomologists are in a position to help the market gardener to the same extent as they can help the fruit grower in the control of diseases and pests. In many cases the methods of control suggested are ineffective and in others they are not applicable to large scale cultures. There are three serious diseases of onions for the control of which practically nothing can be done : onion mildew, white rot and neck rot. Given suitable weather no amount of spraying will prevent the spread of mildew ; and no control has been found for either white rot or neck rot. It is probable that the last word on the subject of controlling these diseases will be said by the plant breeder, for, in the case of each disease, individual plants have been observed showing resistance and even total immunity. Such plants would form valuable material for use in breeding resistant varieties. Onions are quoted merely as examples : some of the diseases for which no effective control is known are leaf spot

of Brassicae ; ring spot, mildew and botrytis rot of lettuce ; mildew and virus disease of peas ; canker of parsnips. In all these cases, it is probable that the plant breeder will in the end provide the solution of the problem.

The control of insect pests does not present so many difficulties. Insects are usually accessible : they are not at work, like so many fungi, within the tissues of the plant where sprays and dusts cannot reach them. Aphids and flea beetles can be readily controlled by dusting with nicotine powders ; cut-worms and leather jackets can be easily poisoned by a mixture of bran and Paris green. Nevertheless certain serious pests remain practically uncontrollable ; such as pea midge and pea thrips ; and, worst of all, the cabbage root fly and the onion fly. The case of the cabbage root fly is interesting in that it offers an instance of the difficulty of applying remedies worked out by laboratory entomologists on small scale plots. It has been found that if plants are watered with a solution of corrosive sublimate during the period when the female cabbage root fly is laying her eggs the larvæ of the fly will be poisoned and the plants escape serious injury. There are about 10,800 cauliflower plants to the acre, at two by two feet : not much imagination is required to visualize the difficulty of giving every cauliflower plant in, say, ten acres of ground its allotted half pint of carefully prepared solution.

Meanwhile, the stereotyped advice that one should refrain from growing the susceptible crop for a period of years is no more palatable than the text-book advice on manuring : *i.e.*, that "stable manure should be applied to a previous crop."

Marketing.—Knowing how to sell a crop is nowadays at least as important as knowing how to grow it. The time has gone by when any sort of greenstuff packed anyhow in any kind of container would bring in profitable returns. Not only is there severe competition between home growers, but continental market gardeners in the case of some vegetables make a dead set at our markets and they are careful to send in nothing but high-quality produce, graded and packed in standard sized non-returnable containers. It is the story of competition in fruit over again. And, as in the case of fruit, the salesman likes to know exactly what he is selling. It saves time, trouble and temper if he knows that a crate of lettuce or cauliflower contains a guaranteed number of heads and that each head will be of a specified size and quality. The old-fashioned grower who formerly bundled his heads of cos lettuce of all sizes into a sack together with soil, roots and dead leaves does not stand a chance in the better class markets against carefully packed and graded produce.

As in the case of fruit, the grower who concentrates his efforts on exploiting a local market, either through retailers or by direct supply, need not be so careful as the grower who sends to the big markets in London or large provincial towns. But some care is necessary : foreign crated lettuce, for instance, penetrates almost everywhere and against this selected and graded material competition is impossible unless correct marketing methods are adopted.

As competition increases, and there is every sign of increase, there will be less and less room for low-grade produce. In the case of fruit there is now practically no room at all and a similar stage will in all probability soon be reached with vegetables.

There is a science of marketing and since in this country the business of selling the crop cannot be handed over to specialists it behoves the grower to study this science himself. He should pay attention to the following points which are essential for success: (*a*) his produce should be seasonable; that is to say, in demand; (*b*) it should be carefully graded for size and quality; (*c*) he must pack well in packages of convenient size and shape; (*d*) he should study market conditions in order to avoid gluts and low prices.

The advantages to market gardeners of co-operative organizations for packing, grading and distributing produce are obvious. They would improve packing and grading, standardize produce, develop markets, save expense in handling and distributing, advertise the produce of their members and keep growers in touch with market conditions.

As it is, the small grower sending his produce to a large market is as often as not like a man fumbling in a dark room. He is at the mercy of commission agents, fluctuating market conditions and the changeable taste of a public now accustomed to a high standard of living. The large scale grower with his telephone, his organization and his command of transport has many advantages which the solitary small scale man can never possess unless he co-operates with his fellows.

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CHAPTER XVI.

THE DISEASES OF PLANTS CAUSED BY FUNGI.

THERE is no clearly defined boundary between a healthy and an unhealthy condition in plants. In practice yield is a common criterion of good health, for it is generally recognized that a large crop cannot be produced when the plants composing it are in an unhealthy condition. The unhealthy condition of the crop may, however, be due to a variety of causes, such, for instance, as the lack of an ample supply of food materials in the soil, drought or even an excess of moisture leading to an inadequate air supply for the root system. It may also be the result of the tissues of the plants being invaded by some parasite. Their normal functions are then

upset and the general health of the plant suffers. In such cases the plants are said to be " blighted " or " diseased." The disease may be so slight that the diminution in the yield of the crop is overlooked, or it may be so severe that the crop fails completely.

The two main agencies in producing diseases in plants are fungi and insects. The fungi are a lowly group of plants marked off sharply from all others by the fact that they are completely lacking in chlorophyll. As a consequence they cannot build up the food required for their growth from the simple inorganic substances of the soil and the carbon dioxide of the air. In order to live they require, therefore, a ready elaborated supply of complex organic materials, such as carbohydrates and proteins. The main sources from which such supplies are obtained are either living plants or their dead remains. The fungi would thus appear to fall into two groups, namely, those dependent on a living host plant, or " parasites," and those capable of feeding on dead plant tissues or " saprophytes." The distinction, though a useful, is not an absolute one, for some fungi bridge the gap by living saprophytically for a time and then becoming parasites. The parasitic or disease-producing fungi naturally appear to be the most important from the plant grower's point of view. But without the saprophytes there would be no agriculture, for they play a fundamental part in breaking down and returning to the soil and air the materials locked up by the growth of previous generations of plants. Their activity in this direction has its troublesome side when it is responsible for the destruction of timber used in farm buildings, gate posts, stakes, etc.

Structurally, the fungi are far simpler than all other plants, with the exception of the algae. The fungus body is, with rare exceptions, built up of microscopic, thin-walled, branching " hyphae," collectively known as " mycelium." It may be so small that it is invisible to the unaided eye, or it may be large, as in mushrooms or puff-balls, but even in these the body is built up of interwoven hyphæ and it shows none of the differentiation into various tissues such as is seen in the higher plants. Reproduction is effected by means of spores formed either vegetatively by the simple abstriction of the tip of a hypha (Fig. 65) or by its segmentation into a chain of spores (Fig. 62), or again, as the result of a sexual process. Most fungi produce two or more forms of spores which are often so unlike one another that, before the life history of the fungus was worked out, the different stages of development were classified in totally different groups. The various forms of spores fall into two broad categories, namely, those responsible for the rapid multiplication of the fungus and those by means of which it tides over periods of adverse climatic conditions or contrives to persist in the absence of its host plant. Those of the former group are usually short-lived, and their efficacy as agents of infection is very dependent upon weather conditions. A short spell of dry weather results in the wholesale destruction of the zoospores of the fungus responsible for potato blight (p. 369) for instance, whilst a hot, dry season may do

much to prevent severe outbreaks of yellow rust by killing off its uredospores. Those of the latter group, the so-called "resting spores," often have a lengthy period of life even under conditions inimical to growth Their walls are commonly thick and dark in colour, or, where this is not the case, the spores are enclosed in resistant fruiting bodies. Probably the majority of resting spores start into growth in the spring following their development, their germination often being dependent upon a thorough freezing, but a considerable percentage of them may remain for years in a dormant condition. Thus, spores of the fungus responsible for the disease known as "bunt" in wheat, taken from herbarium specimens known to be twelve years old, have been found to retain their germinating capacity. Some fungi develop special structures described as "sclerotia" which also have this function. These consist of masses of mycelium, richly stored with foodstuffs, with their outermost hyphæ thickened and dark in colour. The spores of fungi are, without exception, very minute bodies though they differ much in size in different kinds of fungi. They are, moreover, produced in enormous numbers, and though figures which have to be expressed in millions mean little, it is as well to try to realize how abundantly they are formed. The spores of "bunt" (p. 389) are comparatively large, but a single bunted ear of wheat may contain 250,000,000 of them. Suppose now that each of them was the size of a wheat grain, then the produce of one ear would fill about 100 four-bushel sacks.

The dispersal of fungus spores is effected mainly by air currents, and at some seasons of the year, except immediately after heavy falls of rain, it is literally true that the air is full of them. On adhesive surfaces an inch square, exposed in the neighbourhood of a rusty wheat crop, hundreds have been found to settle in the course of a day. Such facts may provide the answer to the question "where did the disease come from?" In addition to this mode of distribution, the spores of some fungi adhere to the coats of grain and seeds, with the result that a supply of them may be, unwittingly, purchased from seed merchants. Dispersal by insect agency also occurs, one of the best known examples being provided by the ergot fungus occurring on rye and a number of the grasses.

Parasitic fungi gain an entrance to the tissues of their host plants in various ways. Some are only capable of attacking them at the seedling stage, for instance, the "white rust" of the Crucifers and the various "smuts" of the cereals, so that once this stage is safely passed there is no likelihood of the plant becoming diseased. More generally, though, the spores germinate on the surface of a leaf or on the epidermis of a young twig, and give rise to hyphae, which either penetrate between the guard cells of the stomata (p. 383) or bore directly through the cuticle. In the former case the mycelium usually ramifies widely through the plant tissues in the latter, though this may also occur, it often spreads no further than the epidermal cells or may even be confined to the actual

thickness of the cuticle. Other fungi are incapable of attacking sound and healthy plant tissues, and to gain an effective entry into their hosts the spores must germinate on wounds formed, for instance, by insect punctures, by hail stones, by the breaking of branches or even by the natural falling of leaves. Such fungi are known as "wound parasites." Once an entry has been secured the hyphae spread either between the cells of their host plant, so forming an "intercellular" mycelium, or by boring directly through them, that is growing "intracellularly." In the former case the actual contact of the fungus with its host's cell-contents is effected by means of button-like or branching suckers, or "haustoria." (Fig. 55.)

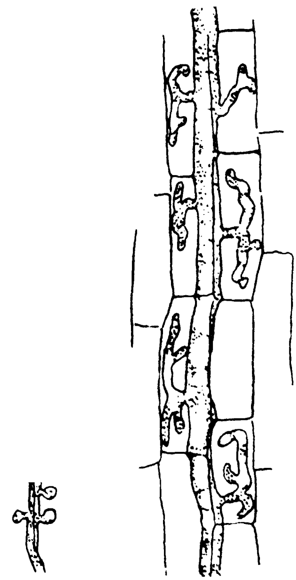


FIG. 55.—Intercellular mycelia with small button-like and with branching haustoria.

The penetration of the tissues does not necessarily result in immediate and obvious damage to the plant.. It may, indeed, have no visible effect for some time, as, for instance, in the case of cereal infections by smuts, where infection occurs at the seedling stage and its results are only apparent as the ears begin to push clear of the sheaths. It commonly acts as a stimulus to the further growth of the infected tissues. Thus, flowers of charlock, normally about half-an-inch in diameter, when attacked by the downy mildew are often two inches across and so hypertrophied that the various organs composing them are hardly recognizable (Fig. 56). At the same time the stems become abnormally thickened and contorted. Galls or tumour-like outgrowths are in fact, common symptoms of disease. The thin-walled, succulent tissue of which they are composed generally dies prematurely, often after being invaded by moulds and other saprophytic fungi. Many fungi, however, do not gradually drain their host plants of the foodstuffs they require, but they bring about the immediate death of the cells with which they come into contact. The track of their mycelium is then marked by brown, dead tissues. Where woody tissues, incapable of further growth and functioning only passively as a water carrying system, are invaded, the actual blocking of the vessels by solid masses of mycelium may result in the sudden death of branches or even of the whole tree. The lignified walls may also be destroyed, with the result that the wood crumbles into touch-wood.

The fungi show great specialization and are generally only

capable of attacking either a particular host plant or a limited range of closely related species. As knowledge of their life histories accumulates it becomes clear that this specialization is sharper than was anticipated. Thus it was formerly considered that the smut of wheat, barley and oats was caused by a single fungus *Ustilago carbo*, but it is now known that a number of distinct species are the causative agents, and that the species which occurs on wheat cannot attack barley or oats. The "black" or "stem" rust known on many grasses, as well as the cereals, is due, however, to a single species, *Puccinia graminis*, but within this species there are numerous strains with sharply limited infective capacities which prevent its indiscriminate spread amongst the wild and cultivated Gramineæ. Where the specialization is less marked the parasites are generally confined to the limits of a particular Natural Order. Thus the fungus responsible for the "finger and toe" disease of swedes and turnips is capable of attacking a considerable number of other Cruciferous plants, or again, the "blight" of the potato may occur on other members of the Solanaceæ, but neither can infect plants outside of these two groups.

FIG. 56.

Hypertrophy of flower and inflorescence of charlock caused by the downy mildew *Peronospora parasitica*.

The extent to which fungi attack their host plants, or the intensity of an outbreak of disease, is largely dependent on the environment. The conditions of both the soil and of the atmosphere play an important part. As a rule the plants growing in the most fertile soil are those which are most badly attacked. Thus the use of nitrogenous manures in attempts to produce exceptionally heavy crops may defeat its own purpose by inducing a severe attack of some fungoid disease. Crops grown with the aid of potash salts, on the other hand, are often comparatively slightly attacked, and the same is often true of crops grown under starvation conditions. A sour condition, easily remedied by the use of lime, is favourable for the development of the soil-inhabiting finger and toe fungus, and consequently for outbreaks of this disease.

The fact that weather conditions largely determine the extent to which crops are attacked has been recognized from the earliest historical times. Indeed it was not until the fact had been established that fungi were the direct cause of plant diseases that the view was abandoned that the weather was solely responsible for epidemics of disease. All parasitic fungi do not require precisely the same conditions for their best development. Moist weather is, on the whole, favourable for the spread of most of the serious

agricultural pests occurring in this country, but some fungi, such, for instance, as the mildews, thrive best in dry seasons. A supply of moisture is clearly necessary for the germination of fungus spores, but the process does not require long extended wet conditions. It takes place quickly, and a film of dew lasting for a few hours only is sufficient for the spores of many fungi to start into growth and so gain a footing in the tissues of their host. Temperature, too, is important, partly because high temperatures may lead to the dessication and death of thin-walled spores and partly because their germination only takes place within certain limits.

Considerable progress has now been made with the study of methods for minimizing, if not always actually preventing, the enormous losses caused every season by the attacks of parasitic fungi. A knowledge of their life histories is particularly valuable when attempts are being made to devise methods for controlling them, as it usually reveals the stage of growth at which measures can be applied with the best chances of success. It cannot be said to be essential though, for bunt in wheat was brought under control centuries before it was known to be the results of a fungus attack, and some measure of control was secured over wheat rust by the middle of the eighteenth century. These, however, are exceptional cases, and the methods used were primarily due to shrewd observation and lucky accident. The life histories of most of the important disease-producing species have now been worked out in considerable detail and, in addition, information is rapidly accumulating with regard to the environmental conditions which are suitable or unsuitable for their development.

The methods in use for controlling plant diseases are for the most part preventive rather than curative. Once the mycelium has established itself it is in most cases more or less deeply buried in the tissues of its host and so out of reach. A cure consequently necessitates a surgical operation which, though practicable in the case of infected tree branches, which can easily be cut out, is out of the question where crops of herbaceous plants are concerned. The preventive methods in general use are of several types, depending upon the stage in the life history of the parasite at which an attack can be made most effectively. The resting spore stage often lends itself to this purpose. If it develops, as it frequently does, on fallen leaves, the gathering up and destruction of dead foliage will go a long way towards preventing infection in the following spring. Where they are formed by soil inhabiting fungi, the omission of the one crop they are capable of attacking gives them no opportunity of perpetuating their kind. Another possibility of control is introduced by the fact that many fungi have definite growth seasons, and it is thus occasionally possible to produce a crop before or after its particular parasite has put in its appearance. In this country a crop of early potatoes will generally escape blight. This method of dodging a disease is being used for minimizing the losses due to black rust in the United States, early maturing wheats being grown

for the purpose. The direct prevention of infection by coating plants with a material which will kill any spores which germinate on its surface, that is spraying or dusting with a fungicide, is also in very general use. In addition to these direct methods of attacking or dodging plant parasites, another means of avoiding the losses they cause is being sought in the raising of plants capable of resisting, either partially or completely, those species which normally attack them. The possibility of this is dependent upon the fact that there is in existence a large number of varieties of most of the crop plants, and when these are exposed to infection, under uniform conditions of growth, they show very different degrees of susceptibility, some even proving immune. This capacity of resisting the disease is known to be inheritable, as a rule in a simple Mendelian manner (p. 406), and thus the synthesis of new resistant varieties has become practicable.

One other aspect of the problem of controlling the fungoid diseases of plants has received much attention of late years. The fact has been recognized that widespread as many of the important ones already are, all of them are by no means universally distributed. Many countries, for instance, though growing potatoes, know nothing of wart disease or even of blight. It may be that local conditions are unsuitable for the growth of some particular fungus or, on the other hand, its absence may be due to the fact that it has, so far, failed to reach that country. The wide seas provide a fairly efficient barrier to the passage of fungus spores either when borne on the wind or when being transported with seeds, packing materials, etc., the period of transit often, though not always, being sufficient to allow of their death. There is obviously much to be said for trying to prevent the introduction of new diseases, especially when it is realized that on their first appearance they are often particularly destructive. This is only possible by definitely forbidding the importation of plants or seeds likely to carry them. The matter, unfortunately, cannot be left to the common sense of individuals. Most countries now have legislation designed for this purpose. It commonly takes the form of either completely preventing the importation of any plants or seeds likely to carry certain specified pests or permits their importation under conditions amounting to a quarantine, when, in the event of an outbreak of the disease in question, the plant can be immediately destroyed. In other countries, particularly some of our Colonies, which are mindful of the fact that the promising new industry in Ceylon of coffee-growing was wiped out by a fungus pest, a more or less universal prohibition of plant importation is in force. Where this holds, the local Agricultural Departments only can introduce and test the suitability of a new plant for general cultivation. In this country the Destructive Insects and Pests Act has from time to time prohibited the importation of a comparatively small number of specified plants. It also prescribes the measures to be used in checking the spread of a number of new or newly introduced pests.

In the following section the life history of a number of parasitic fungi, together with the symptoms of the diseases they cause and the methods used in controlling their spread, are described. Many important species have been omitted, and those dealt with have been chosen largely because they provide examples of the various methods in use for the control of plant diseases.

MYXOMYCETES.

Plasmodiophora brassicae, the organism responsible for the disease known as "club-root" or "finger and toe," belongs to the group of slime fungi or Myxomycetes. This group appears to be related on the one hand to some of the lower fungi and on the other

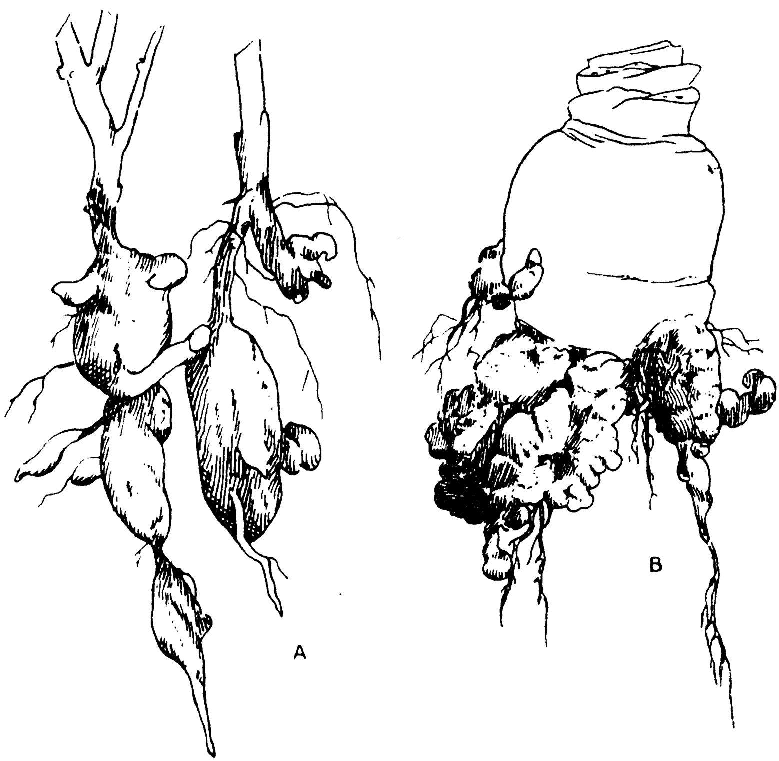


FIG. 57.—*Plasmodiophora brassicae.* Finger and toe on A, charlock and B, swede.

to some of the Protozoa. Its members completely lack the mycelium characteristic of most fungi and consist simply of masses of multinucleate protoplasm with no defining walls. This "plasmodium" breaks up into small spherical spores. On germination these produce amœba-like swarm spores capable of changing their

shape and travelling by a slow creeping movement. Few of the species are parasitic. *P. brassicae* attacks many kinds of Cruciferous plants. It is a serious pest on a number of the Brassicae, such as swedes, turnips, kohl-rabi and cabbage, whilst other common hosts are wallflowers and stocks, charlock and shepherd's purse.

The symptoms of the disease are confined to the root system. On the swollen tap roots of swedes and turnips nodule-like swellings are formed which are often grouped together into irregular masses (Fig. 57). These hypertrophied tissues remain firm during the summer months, but as the autumn advances they decay and form a foul-smelling brown mass. By the use of appropriate staining

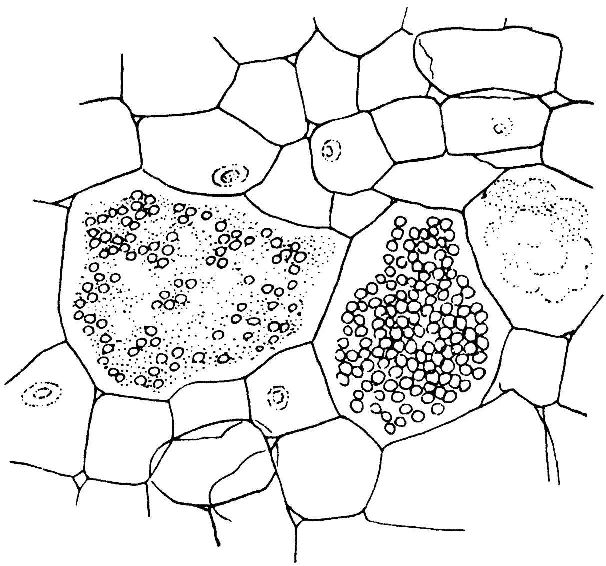


FIG. 58.—*Plasmodiophora brassicae*, FINGER AND TOE.
Section of a diseased portion of the root of a swede showing giant cells and stages of spore formation.

methods the plasmodial stage can be demonstrated in preparations made from material collected during the summer. It occupies, for the most part, abnormally large cells (Fig. 58), the contents of which, in unstained preparations, appear to be normal. Towards the end of the summer the mass of protoplasm gives rise to small rounded spores which more or less completely fill the " giant cells." The spores are set free on the decay of the hypertrophied mass of tissue. On germination each gives rise to a uniciliate body capable of moving about in the soil water. This swarming stage is a temporary one which soon gives place to a slow moving amœboid stage. Apparently either can bring about the infection of the root hairs or the superficial cells of young roots. Once an entry has been

effected the protoplasm increases rapidly in bulk and it may subdivide to form more than one plasmodium in a cell. As fresh cells are penetrated they are stimulated into further development, so forming the giant cells and the mass of the gall-like growths. The organism is only capable of attacking the root systems of Cruciferous plants. Thus, if no such crop and no Cruciferous weeds are grown on land contaminated by it, the disease should quickly disappear. The omission of swedes from their place in a four-course rotation may, however, not be sufficient to stamp out the disease owing, probably, to the persistance of the spore stage.

The disease is particularly prevalent on soils which are deficient in lime. Its occurrence is indeed as reliable an indicator of this condition as the growth of such weeds as spurrey or sheep's sorrel. The fact points the way to one method of controlling the disease. This is to apply heavy dressings of lime to the fields, preferably as soon as the infected crops have been removed. A ton an acre is not an extravagant dressing, and still more may be used profitably on soil which is in a thoroughly sour condition. The use of any manure, such as ammonium sulphate, which tends to increase soil acidity, is obviously inadvisable. The disposal of diseased crops requires careful consideration when attempts are being made to eradicate the pest. If the roots are used for feeding in yards fragments of diseased ones may be dropped into the litter and so find their way to the manure heap. The spores they contain are not easily killed, with the result that the manure may infect soil in which the organism is not yet present. If the roots are fed on grassland the chances of their spreading the disease are appreciably diminished. They are not entirely eliminated, however, for spore-containing soil or manure adhering to the workers' boots may still find its way to the arable land.

Where crops of transplanted Cruciferous plants are grown, such as, for instance, cabbages, Brussel sprouts or swedes for seed purposes, symptoms of the disease can often be seen on the root systems. If no stock above suspicion is available the bundles of seedlings should be looked over before taking them to the fields, the infected plants destroyed and the roots of the remainder dipped in a suspension of lime and clay.

In gardens soil infected with the finger and toe organism may be treated with a dilute solution of corrosive sublimate (one ounce in 10—15 gallons of water). This may be used with good results either for occasionally watering seed-beds or for watering-in recently transplanted plants.

Comparative trials of large numbers of varieties of swedes on badly contaminated soil have shown that all of them are not equally heavily infected. So far, none have been found to be completely immune to the attacks of the finger and toe organism. But several have proved to be sufficiently resistant to produce good crops under conditions in which most kinds fail badly. The most resistant sorts are the Danish Bangholm strains and Bruce. Their discovery

marks a fresh stage in the control of this singularly troublesome pest, for it holds out the hope that plant breeders will be able to produce still more resistant types.

PHYCOMYCETES.

Synchytrium endobioticum is responsible for the "wart disease" or "black scab" of the potato. It belongs to a lowly group of fungi, one of the distinguishing features of which is that most of its members completely lack a mycelium. The fungus body thus consists of nothing more than reproductive bodies. The origin of the disease is inexplicable at present. Plants attacked by it show such obvious and unmistakeable symptoms that its presence cannot possibly be overlooked. Yet it was unknown until late in the nineteenth century, when it was found in Hungary. It is now known to occur throughout Europe, and it has spread, probably through the importation of infected seed tubers, to Canada, the

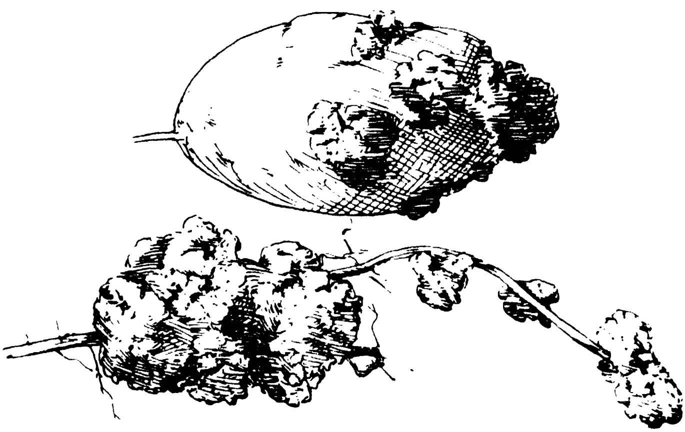


FIG 59.—*Synchytrium endobioticum.* WART DISEASE OF THE POTATO.

United States and South Africa. It was first recorded in this country in 1900 in Cheshire and Lancashire. From these counties it has spread mainly in a northerly and southerly direction and, at present, it is confined to approximately the western and midland parts of the country. Sporadic outbreaks have occurred in a few of the eastern counties, but spreading from these centres of infection has been prevented.

The haulm and foliage of infected plants has a normal appearance and the disease only becomes evident at lifting time. Then the tubers are found to bear rough-surfaced, rounded or irregular, tumour-like masses. These "warts" vary much in size: on slightly attacked tubers they are little more than small, rough swellings situated invariably on the eyes, but in bad attacks the whole surface of the tuber may be covered with them (Fig. 59).

They usually begin to develop at the period when the plants come into flower. In the early stages of their growth they are light in colour and not unlike pieces of the curd of a cauliflower, but as they age they turn to a deep brown or black and quickly decay if their surroundings are moist.

The warts owe their origin to the presence of a resting stage of the fungus in the soil which may be the result of the infection of a previous crop, or which may have been introduced with the seed tubers. This stage is a roughly spherical, thick-walled, dark brown "sporangium," which, under suitable conditions, liberates its contents in the form of a number of mobile uniciliate zoospores (Fig. 60).

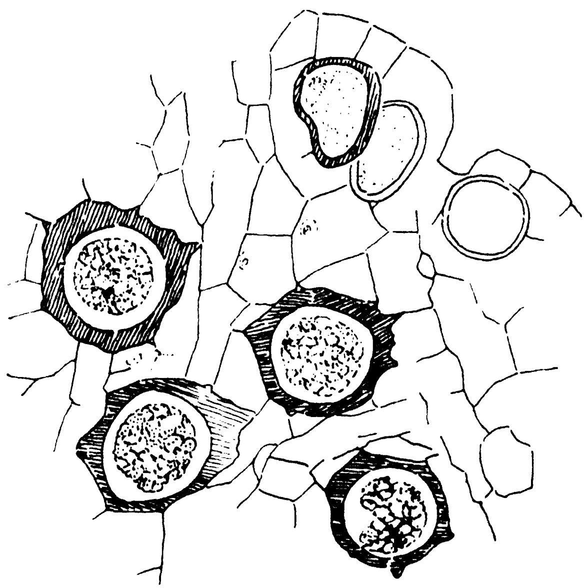


FIG. 60.—WART DISEASE OF THE POTATO (*Synchytrium endobioticum*). Resting spores in various stages of development.

Should one of these zoospores come into contact with the unsuberized tissue of the eye of a young tuber, infection occurs. This is followed by the repeated divisions of the neighbouring cells, resulting in the formation of a mass of succulent tissue which in turn is very liable to fresh infections. In this large numbers of sporangia but no signs of hyphae develop. These again give rise to mobile zoospores which can either re-infect neighbouring cells or tubers in their immediate neighbourhood or they may act as gametes and fuse in pairs. The fusion-products on infecting fresh tissues give rise to the thick-walled resting sporangia which are set free in the soil on the decay of the warts. They are capable of living for some years, with the result that the omission of the potato crop once in a four-year rotation will not necessarily free the soil from infection.

The continuous growth of the crop on allotments and in gardens soon leads to such an accumulation of them that it is impossible to produce sound tubers of certain varieties under such conditions. Fortunately, though, it was found early in the story of the disease that some varieties, even though growing on heavily infected soil, entirely escaped it. A method of checking the spread of the disease was therefore available almost at its outset. This was promptly taken advantage of. The disease was scheduled under the Destructive Insects and Pests Act, and the compulsory notification of all outbreaks was insisted on. Areas in which the disease was present were then defined, and within these the growth of other than immune varieties was prohibited. Further, the sale for seed purposes of tubers from such crops was forbidden, except in the scheduled areas, on the grounds that though free from disease themselves, any soil adhering to them might carry infection to uncontaminated soil. These measures, which have been subject to various changes as the circumstances warranted, have proved effective and the disease has been kept out of several of the most important potato growing districts. Growers in districts where the soil is still charged with the resting stage have, however, to content themselves with the cultivation of immune varieties. They can choose, amongst others, from Ally, Arran Comrade, Edzell Blue, Great Scot, Abundance, Tinwald Perfection, Flourball, Golden Wonder, Kerr's Pink and Longworthy. But the list does not include such popular varieties as Up-to-Date, King Edward and Majestic. The problem of finally controlling the disease rests with the production of immune varieties to take the place of these latter. The mode of inheritance of immunity and susceptibility has now been investigated and found to take place on simple Mendelian lines (p. 406), and thus the raising of varieties which the fungus cannot attack is a relatively simple matter. The difficulty, however, is to raise sorts which, whilst possessing immunity, are equal in every respect to the best known. The breeder has to produce large numbers in the hopes of finding one or two worthy of general cultivation. One of his difficulties is to test the most promising forms to determine how they will behave when exposed to the attacks of the fungus. To overcome this a testing station has been established by the Ministry of Agriculture and Fisheries at Ormskirk, in Lancashire, where the new varieties are grown on soil deliberately kept in a highly contaminated condition. The results of the first trial cannot be considered to be final for, where only a few tubers can be tested owing to the scarcity of the stock, there is a possibility of their escaping infection, especially in a dry season. Immunity cannot, therefore, be guaranteed unless the tests extend over two years. This entails a delay in working up stocks of new varieties which may be of considerable value to the raisers. To avoid this several laboratory methods have been worked out. The most rapid of these depends on the fact that if a piece of a fresh wart is moistened with water zoospores will soon begin to swarm

over its surface. If, then, a small fragment is placed in contact with an eye which is beginning to shoot, infection, if it is possible, will occur immediately and the results will be visible in a few weeks. The work of multiplication can then proceed immediately with every confidence that the new variety will, when tested at Ormskirk, be placed in the official list of "immunes."

Potato Blight.—The potato crop, from the time of its introduction in Elizabethan days until about the year 1845, does not appear to have suffered from this well-known disease. In that year it broke out in the Isle of Wight about the middle of August, and in the course of a few weeks spread throughout the country and Scotland and Ireland. Contemporary accounts state that it destroyed between one quarter and one half of the crop. In the following year an epidemic started earlier, and was even more destructive. In Ireland it was so severe that nine-tenths of the crop rotted. The Irish famine of 1846 was the direct result of this outbreak.

Since then the fungus responsible for the disease (*Phytophthora infestans*) has always been present, and though satisfactory methods for controlling its spread are well known, it occasionally causes very severe losses to potato growers. It attacks all of the cultivated varieties of the potato, most of the species related to *Solanum tuberosum*, and some other Solanaceous plants, such as tomatoes and petunias. The intensity of its attacks differ on different kinds of potatoes, but whilst some may practically escape disease in favourable seasons, they usually become badly infected when the climatic conditions are particularly favourable for an outbreak of blight. Such a variety as Evergood, for instance, will often show only slight signs of disease, whilst neighbouring crops of Up-to-Date or King Edwards are badly attacked, but in a severe epidemic it, too, will suffer severely. Another example, now of historic interest only, is provided by the variety Champion. This was very generally grown in Ireland solely on account of its resistance to the attacks of Phytophthora, and even in the epidemic of 1879 it was only slightly damaged. It has now lost its powers of resistance, owing, probably, to its having become infected with virus diseases, and is consequently of little value.

The first symptoms of the disease are the appearance of dark green, water-sodden patches on the tips and margins of the leaves. The patches increase in size and number from day to day, turning, as they age, to a dark brown colour. The disease generally spreads with extraordinary rapidity, and it is not unusual for every plant in a field to be infected a fortnight after its first appearance. Whilst it spreads the diseased crop has a characteristic musk-like odour. The tubers of infected plants show discoloured and slightly depressed areas on the surface, and when cut across, rusty-brown stains extending inwards from the skin. If stored they decay rapidly, but the rotting is the work of other organisms, mainly bacteria, which invade the infected tissue.

The fungus can easily be obtained for examination by placing a few freshly infected leaves in a vessel of water and covering it with a bell-jar. A grey coloured, fluffy coating soon develops towards the margin of the infected areas. This consists of branching hyphæ which stand up from the stomata and bear lemon-shaped conidia (Fig. 61). A light breeze or the slightest jar is sufficient to detach them when ripe. If placed in water they give rise to a number of minute, biciliate, motile zoospores which are capable of germinating and under suitable conditions of infecting healthy potato foliage. In the field these processes occur on leaves covered with a film of dew or wetted by rain. The hypha arising from the germinating zoospore pushes its way between the guard cells of a stoma, and develops a mycelium which grows between the cells of the host and drives suckers or "haustoria" into them. Wherever it comes into contact with them the cells die immediately and become brown in colour. The tubers may be infected through the lenticels or possibly through slight abrasions of the skin caused during lifting operations. Their cells are killed and discoloured in the same manner. But the starchy contents are not affected, so that diseased tubers can still be used for the preparation of starch or alcohol.

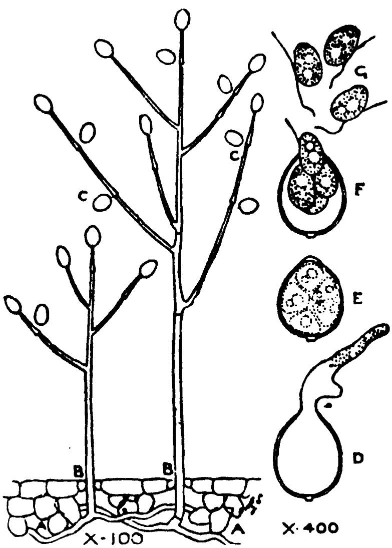


FIG. 61.—POTATO DISEASE FUNGUS, *Phytophthora infestans* De Bary.

A, part of interior of lower surface of potato leaf, showing mycelium of potato fungus ramifying amongst the cellular tissues of the leaf.

B, branches of fungus emerging through stomata.

C, conidia.

D, conidium germinating and producing mycelium.

E, another conidium, its contents differentiating into zoospores.

F, conidium opening, and emitting zoospores.

G, free zoospores.

In some fungi which resemble *Phytophthora infestans* very closely, thick-walled resting spores capable of surviving through the winter are formed. These germinate in the following spring, or even a year or more later, and thus ensure the life continuity of the fungus, which otherwise would be broken by the death of the readily perishable conidia and zoospores. Similar resting spores have been obtained in laboratory cultures of the blight fungus, but their occurrence has not been satisfactorily demonstrated in the open. Many attempts

have been made to determine precisely how it overwinters here and persists from year to year. That infected tubers should give rise to diseased plants seems inevitable, yet they do not invariably or, perhaps, generally do so. The fact that the first outbreaks of disease on a farm are frequently to be found on "volunteer" potatoes in the immediate vicinity of old potato pits is, however, strongly suggestive of their doing so. But whether the mycelium passes into the shoots and thence to the developing haulm and foliage, where it produces a crop of conidia, or whether these are produced directly on exposed infected tubers, is still uncertain.

It has long been recognized that weather conditions are mainly responsible for the severity of outbreaks of potato blight, and that damp, muggy conditions, especially during the latter part of July, are almost invariably associated with more or less severe epidemics. Such conditions are peculiarly favourable for the development of the fungus. The motility of the zoospores is clearly dependent upon a film of moisture on the foliage and stems, and the more persistent it is the better are the opportunities offered for their germination and subsequently for their bringing about infection. The atmosphere within the shelter of the crop, kept as it is moisture-laden by the transpiration of the leaves, is ideal for their growth. Rain, too, splashing on clusters of conidia must help appreciably in transferring them from plant to plant. Dry weather, on the other hand, is unfavourable for the fungus, for without water the conidia cannot germinate, neither can the zoospores bring about infection, and they soon die.

Temperature also plays a decisive part in determining whether the disease will spread rapidly once it has made an appearance. The activity of the zoospores of the fungus is dependent on it. At low temperatures such as 5°—6° C. they retain their power of movement for 24 hours, but as the temperature rises they lose it rapidly, and at 24°—25° C. they cease to move in about 20 minutes. High temperatures thus diminish the chances of infection and make a severe epidemic improbable.

The conditions under which outbreaks are most likely to occur have now been defined with some accuracy. They are (1) a night temperature below the dew point for at least four hours; (2) a temperature not falling below 10° C.; (3) a mean cloudiness of not less than 0·8; and (4) a rainfall of at least 0·1 mm. following in the next 24 hours. When such occur in Holland warnings of the probability of blight appearing are broadcast so that immediate steps may be taken to prevent its attacks.

If it were possible to control these conditions the losses due to blight could be largely avoided. This, however, is only practicable on the small scale when crops are grown under glass. Fortunately there are other methods available. One of these is to take advantage of the fact that in most parts of the country the disease does not make an appearance before the middle of July. A crop of a rapidly growing early potato such as Epicure may consequently

be lifted before it has been exposed to infection. In the Channel Islands, Cornwall and parts of Devonshire, where the earliest crops are grown, the early appearance of the disease, however, often makes it impossible to dodge its attacks.

The method generally adopted for controlling the disease is to coat the foliage and stems of the plants with a thin film of material which will kill the zoospores when they come into contact with it or germinate on its surface. Compounds of copper make the most effective of these fungicides. Two which are used on a large scale are Bordeaux and Burgundy mixtures. There is little to choose between them from the point of view of efficiency, but the latter is often the easier to prepare, as the freshly-burnt lime required for making Bordeaux mixture is not always easily available.

Bordeaux mixture is prepared by mixing together a solution of copper sulphate and a fine suspension of lime in water. Its value depends largely on the care taken in its preparation. Various formulæ are in use. To make up 50 gallons of the mixture 4 lb. of copper sulphate and 4 lb. of freshly burnt lime may be used. The copper sulphate should be guaranteed to be at least 98 per cent. pure, and the lime should be "fat," that is free from lumps of over-burnt vitreous material. The copper sulphate is placed in a wooden tub containing 35 gallons of water, and whilst it dissolves the lime suspension is prepared. The first step in this process is to slake the lime in the minimum quantity of water. This is done most conveniently in a bucket covered with a sack to retain the heat. Then when it has crumbled to a fine powder, enough water is added to allow of its being worked into a smooth, stiff paste which can, by a further addition of water, be reduced to the consistency of thin cream. If this is free from gritty particles it may be added directly to the remaining 15 gallons of water, if otherwise, it should be thinned down further and strained through muslin or a fine wire gauze into it. The lime suspension is then added to the copper sulphate solution, which should be vigorously stirred during the mixing. The resulting sky-blue mixture holds in suspension a flocculent, almost gelatinous precipitate which, if the mixture has been well prepared, settles out very slowly. Before it is used a test should be applied to see that it contains no free copper sulphate, which, though efficient as a fungicide, causes damage through scorching the foliage. A sufficiently accurate test can be made by dipping a clean knife blade into the mixture for half a minute. If a film of copper forms on it more of the lime suspension must be added to the mixture to get rid of the free copper sulphate.

In Burgundy mixture the lime is replaced by washing soda. Again various formulæ are in use. One which is generally satisfactory is 5 lb. of copper sulphate and 7 lb. of washing soda to 50 gallons of water. The ingredients are dissolved separately and mixed as in the case of the preparation of Bordeaux mixture.

These two fungicides should be used in as fresh a condition as possible. If allowed to stand for some time the gelatinous

precipitate loses much of its strikingly adherent properties and tends to become crystalline in character. Its efficiency is then greatly reduced.

The mixture is applied to the crop by means of spraying machines, varying in size from the three-gallon knapsack sprayers readily carried on a man's shoulders up to power-driven machines capable of transporting several hundred gallons and delivering a spray at a pressure of 200 lb. No matter what the size or form of the sprayer is, it must be so constructed that the mixture is delivered in the form of a spray so fine as to be correctly described as "mist-like." It will then settle down gently and form a continuous film on the upper side of the foliage and haulms. The lower surfaces will be coated at the same time by the direct spray from the low-set nozzles. When the plants are dry they appear, after being perfectly sprayed, to be covered with an almost uniform, greyish bloom. After spraying with nozzles which deliver a coarse spray, or when excessive quantities of the fungicide have been used, drops form at the tips of the leaves. These, on drying, leave a heavy sky-blue deposit.

The quantity of either mixture necessary to adequately coat an acre of potatoes varies widely, both with the worker and the type of sprayer used. The limits are about 75 to 150 gallons per acre, with some 120 gallons as an average.

The date at which the crop should be first sprayed varies with the season and the district, but as it is required to prevent the fungus from establishing itself on the crop the work should be carried out immediately before there is a likelihood of its appearing. The first outbreaks in the country are nowadays generally reported in the press or by the British Broadcasting Corporation, and the information is useful even if it only refers to distant localities, for it calls attention to the advisability of having everything in readiness. No very precise dates can be given, but the disease may be expected in the south-west of the country by the middle of June, or even earlier in the milder parts of Cornwall and Devon. Over most of the Midlands and along the south-east coast it may appear about the end of July, from then until the middle of August in the potato-growing districts of East Anglia, and a week or so later in those of Yorkshire, Cheshire and Lancashire.

Fine weather is essential for spraying operations, and no opportunity should be missed of carrying out the work on a still, windless day, when the spray mist will settle down uniformly. Once the coating has dried thoroughly on the foliage it will adhere for a long time, but if rain falls before this happens much of it will be washed away and the operation may have to be repeated. As the crop grows and further foliage is formed, this, in turn, should be protected. This entails a second spraying, generally about three weeks after the first, whilst a third spraying may be given a month later. The number and time of the applications is determined by the weather conditions.

The immediate result of protecting the crop from becoming infected is that the haulm continues to grow for a longer period than it otherwise would. The foliage also continues to carry on its work of carbon assimilation, with the result that larger quantities of starch are available for deposition in the tubers. As a consequence the crop from a field which has been thoroughly sprayed is larger than that from a field in which the foliage has been killed prematurely by blight. Many experiments have shown that the increased yield so obtained may be about two tons to the acre. Even at a low price this will more than cover all of the costs of the sprayings. Moreover, the tubers from the sprayed crop will be free from disease and consequently capable of being stored without loss. If no control of the disease had been effected, zoospores washing through the soil would have infected the tubers, and again at lifting time, further opportunities of infection would have been provided. This latter infection leads to the trouble often known as "after-sickness." The symptoms of the disease only develop when the potatoes have been pitted. Before this work is carried out the tubers will have been sorted, and all showing any signs of blight will have been rejected. But nevertheless rot sets in within a few weeks.

After-sickness can be prevented to a certain extent by late lifting, for by then the haulms and foliage will be completely dead and the spores they have produced will have perished. Failing this the diseased haulm may be cut off and removed from the field a week or so before it is required to harvest the crop. In unsprayed crops the losses due to the infection of the tubers whilst growing may be partially prevented by earthing up the rows heavily. A thickness of three inches of soil acts as a fairly efficient filter and prevents most of the zoospores reaching the tubers.

In spite of the unquestioned efficacy of spraying as a means of controlling the disease, some growers prefer to run the risk of losing a great part of their crops. Their considered opinion is that, on the whole, it pays them best to let the disease run its course and market the crop as soon after lifting as is practicable. This is necessary owing to the certainty of decay. This practice is due partly to the fact that the preparation of either Bordeaux or Burgundy mixture is a somewhat troublesome business and partly to the difficulty of spraying at the proper time. The trouble may be avoided by the use of copper-containing fungicides in the form of a fine powder which can be distributed over the crop by means of special bellows. If the work is carried out early in the morning whilst the dew still persists the mixture adheres satisfactorily. This dusting method, though less effective than spraying, gives a fair measure of control over the disease. It, too, suffers from the same defect as spraying. It can only be carried out properly during fine weather, and it is in damp weather that the disease spreads most rapidly.

ASCOMYCETES.

The powdery mildews are responsible for diseases occurring in a wide range of host plants. These include most of the clovers, swedes, many of the Compositae, apples, pears, roses, gooseberries, strawberries, hops, cereals and grasses. The mycelium is superficial and spreads over the foliage, the young shoots, or occasionally the fruits, in the form of a delicate cobweb-like layer. At first this is white in colour, but in some species it becomes grey, brown or black as growth proceeds. It is fixed to the surface of the host plant by haustoria driven through the cuticle of the epidermal cells. These also absorb from the host plant the food material necessary for the growth of the fungus. Though the invasion of the host by the parasite is thus extremely slight, the diseased parts often die prematurely and the mildews are responsible for much damage. From the superficial weft of mycelium upright branches arise. Transverse walls forming in them divide them up into chains of elliptical conidia, which are abstricted one after another. At this stage the surface acquires the characteristic mealy appearance which is responsible for the description of "powdery" mildew. The coating of mycelium then becomes denser and often changes in colour. In the thickened weft small yellow and finally brown or black dots develop. These are the cleistocarps or perithecia of the fungus. They are completely closed globular structures containing one or more club-shaped asci, within each of which are eight ascospores. The wall of the cleistocarp is formed of a layer of darkly coloured close-fitting cells from some of which simple or branched appendages grow. The various genera composing the group of powdery mildews or Erysiphaceae are delimited by characteristics provided by the shape of the appendages and by the number of asci within the cleistocarps. As the conidial chains are very similar to one another in the different genera it is almost impossible to classify a specimen of one of these mildews in the absence of the cleistocarp stage. Thus the common powdery mildew of the vine, which was probably introduced into Europe from America, was only fully identified nearly 50 years after its appearance here in 1845, when cleistocarps were found for the first time in France.

The spreading of the mildews during the growing season of their hosts is brought about by the conidia. When one of these reaches the surface of a leaf or shoot of a suitable host plant it anchors itself by the formation of a sucker-like disc; a hypha is then formed from which an haustorium is soon driven into an epidermal cell. The ascospores within the cleistocarps provide the over-wintering stage of the fungus. They are set free explosively in the spring and early summer, and on germination they give rise to a weft of mycelium similar to that developed from a germinating conidium.

The life history of *Sphaerotheca mors-uvae*, which is responsible for the widely distributed disease known as American gooseberry mildew, is typical of that of most powdery mildews.

The fungus is not indigenous to this country. It was introduced in 1900 into Ireland on gooseberry bushes imported from the United States. The disease spread rapidly throughout N. Ireland and in two years time it had established itself in several of the gooseberry-growing areas of this country. The first of its symptoms appear in May or June in the form of white mildewed areas on the young fruits and on vigorously growing young shoots. This distribution differs from that of a second mildew, *Microsphaera grossulariae* (European gooseberry mildew), which occurs on the same host. In this species the mycelium develops on the foliage only. The disease spreads rapidly throughout the summer months, particularly on young bushes and on any strongly growing shoots of older bushes. Old bushes which make little young wood are less severely attacked. The infected shoots often shed their foliage prematurely and become dwarfed and mis-shapen. In the course of about three weeks, when the formation of conidia ceases, the mycelium acquires a dark brown colour. Cleistocarps can then be found developing on the surface of the scurfy weft (Fig. 62). Finally, on twigs which have over-wintered, it becomes an ashy grey.

Soon after its appearance the disease was scheduled as a noxious pest under the Destructive Insects and Pests Act, and steps were taken to restrict its spread. Growers were required to notify its presence in their gardens and plantations to the (then) Board of Agriculture, and the marketing of infected berries and the distribution of disease-bearing bushes was prohibited. In spite of this fresh outbreaks occurred continuously. The fact that they frequently started in the immediate neighbourhood of packing sheds suggests that infected baskets circulating from one grower to another may have been one of the means by which the parasite was spread rapidly over the country. The failure to localize the disease and exterminate it has led to the necessity of employing control measures wherever the crop is grown. The first of these aims at preventing the first infection in the spring by destroying the resting stage of the fungus. This is effected by cutting off and burning the diseased shoots. The operation must not be performed before the middle of August, for pruning prior to this generally results in the development of considerable numbers of young shoots, which immediately become infected. If postponed too long some of the cleistocarps may become detached and fall to the ground. The soil below the infected bushes should, therefore, be dug over so as to bury them deeply. It is difficult to be certain, especially when large bushes have to be dealt with, that every diseased shoot has been removed. A protective coating of some fungicide, such as Burgundy mixture or lime sulphur, should, therefore, be applied early in the spring. A single spraying will rarely give complete control of the fungus, and in most cases it is necessary to repeat it. This is especially the case where the chances of infection are numerous, as, for instance, in plantations in which the disease has been allowed to establish itself thoroughly. The preparation of the lime sulphur wash from

lime and sulphur is a troublesome process, and it is generally advisable to purchase a ready-made supply. This is now obtainable in drums in the form of a concentrated solution which, as an indication of its strength, should be guaranteed to have a specific gravity of 1·3. To make up the wash one gallon of the concentrated solution should be slowly poured into 29 gallons of water and thoroughly mixed. As this reacts on copper, tin-coated spraying machines must be used.

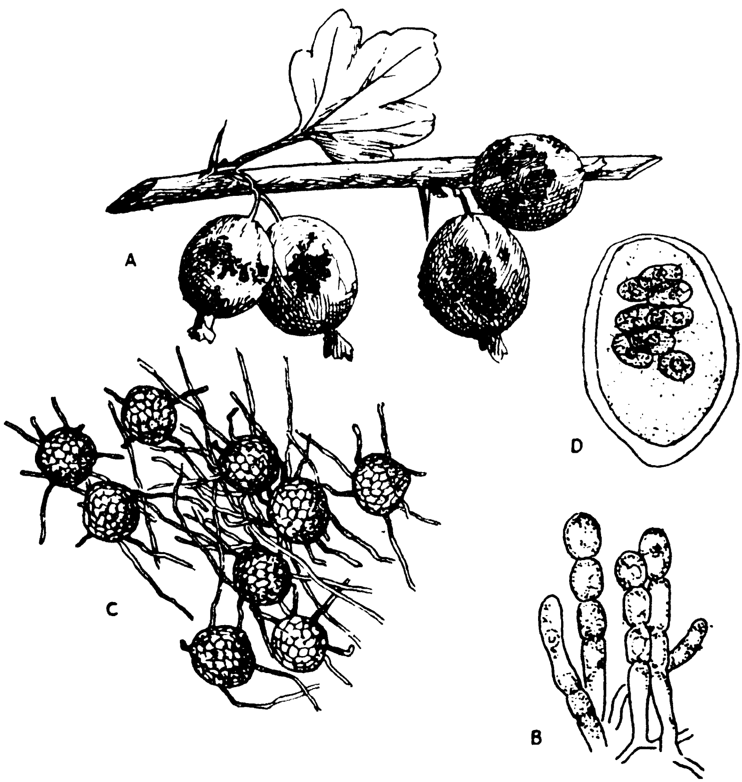


FIG. 62. *Sphaerotheca mors-uvae.* AMERICAN GOOSEBERRY MILDEW.

A, infected berries. C, ripe cleistocarps.
B, chains of conidia. D, ascus.

The first spraying is generally required early in April in order to provide a protectory coating for the young shoots. The exact date, which will vary with the season and the district, is dependent on the state of growth of the bushes. A second spraying should follow in three or four weeks' time. This has two functions ; it will again serve as a measure of protection and, in the event of infection having occurred, it will act as a destructive agent on the superficial mycelium. A third spraying is generally advisable some three

weeks later. This, however, may leave a thin deposit on the berries which, though harmless in itself, depreciates their market value. It can be removed by stirring the berries in a vessel of water.

Lime sulphur used at this strength causes damage to the foliage of some varieties of gooseberries, amongst which are Keepsake, Crown Bob and Lancashire Lad. When these have to be sprayed a more dilute wash should be employed. A suitable dilution is one gallon of the concentrated solution to 59 gallons of water, that is, half the strength of the normal spraying solution.

Sulphur-containing fungicides such as the lime-sulphur wash, a dilute solution of liver of sulphur, or even sulphur itself in the form of finely divided flowers of sulphur, appear to be especially suitable for the control of most powdery mildews. But in spite of the fact that practically the whole of their mycelium is exposed, the diseases they cause are as difficult to contend with as those resulting from the attacks of parasites with a deeply-seated mycelium.

The large group of the Discomycetes, characterized by the fact that the asci at maturity are borne on open, frequently cup-shaped, fruiting bodies or apothecia, contains relatively few parasitic species. It includes, though, the genus Sclerotinia, members of which give rise to a number of destructive diseases on a wide range of cultivated plants. The distinguishing feature of the Sclerotiniae is that they form hard, black masses of mycelium known as sclerotia. As these are capable of withstanding dessication and freezing they function as resting-stages for the fungus. On germination, which is often dependent on a preliminary freezing, they give rise to the apothecia. Those are generally cup- or saucer-like in shape, and borne on slender stalks. The ascospores infect their appropriate host plants directly. From the resulting mycelium a conidial stage may or may not be produced. In some species conidia are produced directly from the sclerotia and the ascus stage may be wanting. The conidia, which generally serve the purpose of distributing the fungi rapidly during the growing season of the host, may either appear in the form of bunches of grapes, as in the well-known Botrytis, or in branching chains.

Sclerotinia Trifoliorum is one of the causes of the common disease known as "clover sickness." As the term is also applied to a disease brought about by the attacks of an eel worm it would be better to describe that due to the fungus as "clover rot."

The first symptoms of clover rot appear in the autumn months on plants arising from sowings made in the previous spring. Older plants are rarely attacked. The early stages of the disease, characterized by the formation of brown spots on the foliage, are not generally noticed, and it is only in the late winter and early spring that its presence becomes obvious. Then the widening patches of dead plants cannot be overlooked. On the upper part of the root and the neck of such plants black sclerotia develop which vary in size from that of a pin's head to a small pea. From these small, pinkish-brown apothecia arise either in the late autumn or early

spring. They are irregularly saucer-shaped and stalked, the length of stalk being determined mainly by the depth of the sclerotium in the soil. The ascospores are capable of immediate germination. The resulting mycelium forms a thin floccose white coating on infected leaves and round the necks of the plants. It spreads most rapidly during wet, mild winters. The hyphæ penetrate the plant's tissues and kill the living cells wherever they come into contact with them. They do not give rise to a conidial stage, and the spreading of the parasite is effected largely by the centrifugal growth of the mycelium from plants initially infected by ascospores.

The fungus attacks red, white and crimson clover, alsike, black medick, lucerne, sainfoin and beans. But its attacks are apparently confined to these plants when grown as arable land crops, for they do not occur on the clovers of long established grassland. Red clover is particularly susceptible to the disease.

In fields where clover-rot has occurred the only method of avoiding further losses is to free the soil from living sclerotia. Most of these produce apothecia within a year of their formation, but some may remain in a dormant condition for a number of years. If the rotation in force requires a clover crop once in four years then it should be omitted once so that the soil does not carry the crop for eight years. By then the chances of viable sclerotia being present are negligible. Failing this the more resistant white clover should be substituted for red.

FIG. 63.—CLOVER SICKNESS (*Sclerotinia trifoliorum*).

Cluster of apothecia growing amongst the remains of a dead clover plant.

Apple Scab.—The most troublesome pest growers of apples have to contend with is *Venturia inaequalis*, the fungus responsible for the disease known as Apple Scab. The damage this causes to the trees is usually slight, though after a severe attack it may appreciably weaken them. The attack on the fruits is of more serious concern to the grower, for though it does not destroy them outright it causes so much disfigurement that their market value is heavily depreciated. The disease occurs in all of the home apple-growing districts as well as being generally distributed in the orchards of all apple-growing countries (Fig. 64).

Its symptoms are usually first noticed on the young foliage on which circular, light-grey spots which turn later to a dull olive green and finally a black colour are formed. In cold, wet seasons they spread rapidly, and by coalescing cover large areas on the leaves. When this occurs it is often followed by a premature leaf-fall, and early in the autumn heavily infected trees may be leafless.

The fruits are often attacked at an early stage of growth. The spotting resembles that on the foliage in being a deep greenish-brown or black colour, but a distinct white margin is often visible. When attacked severely at an early stage of development they frequently fall, and if this should not occur they are dwarfed and deformed. Later infection, which may occur throughout the growing season, is followed by the appearance of isolated or confluent "scabs." The scabbed portions become hard and often crack, with the result that other fungi may find a way into the tissues and cause a speedy rotting. The fungus is not confined to the foliage and fruits. It is usually present, though often overlooked, on young twigs and even on the scales covering their buds. The infected twigs may be distinguished by the appearance of the bark. That of a healthy twig is smooth, whilst that of one in which the fungus is present is roughened and blistered by small masses of submerged mycelium.

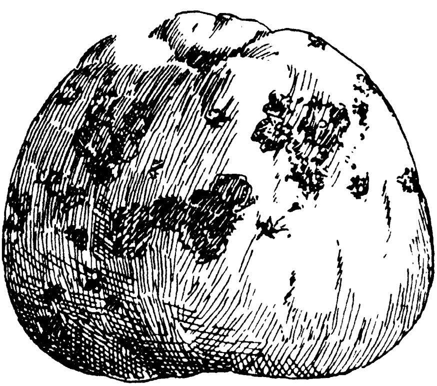


FIG. 64.—APPLE SCAB (*Venturia inaequalis*)

The more active form of the parasite in this country is the conidial stage of the Ascomycete *Venturia inaequalis*, known before its life history had been thoroughly investigated as *Fusicladium dendriticum*. Sections cut through a scab or a leaf spot show a thin, densely woven mass of hyphæ from which short stalks, each terminating in an elliptical or pear-shaped conidium, arise (Fig. 65). These conidia are responsible for the rapid spread of the fungus. They are liberated from the infected twigs and bud scales at the time when the flowers begin to open and the foliage to expand. On falling on to the sepals of a flower, a young fruit or a leaf, they germinate and give rise to a mycelium which spreads and forms a compact layer in the cuticle from which fresh conidia soon develop. Infection may continue then as long as the tree is in an active stage of growth. The mycelium formed in the young twigs remains dormant during the winter months and so provides for the over-wintering of the parasite. This is also effected by the development of a perithecial stage which has only comparatively recently been found in this country though its existence was established some years previously in the United States. It is probably common here but overlooked unless especially searched for. Ripe perithecia are to be found during the early spring on leaves which have lain on the soil during the winter. They are somewhat spherical or

flask-like in shape and open by a neck projecting through the upper surface of the leaf. Within them is a number of club-shaped asci containing eight dark-coloured spores, each of which is divided into two unequal portions by a transverse septum (Fig. 66). The ascospores are ejected explosively only when the perithecia have been thoroughly soaked by rain. For their germination, and also for that of the conidia, sufficiently moist conditions to ensure the presence of a film of water on the surface tissues of the host plant is essential. They also give rise to a cuticular mycelium similar to that produced by the growth of the conidia.

In seasons which are favourable for the disease it is not uncommon for 90 per cent. of the fruit to be affected. The loss can be largely prevented by the systematic use of fungicides, but though it may be possible to reduce it to some 10 or 15 per cent., the production of a scab-free crop is not often effected when the season happens to be cold and wet. As a knowledge of the life history of the fungus suggests, control measures must be taken early in the season. Before

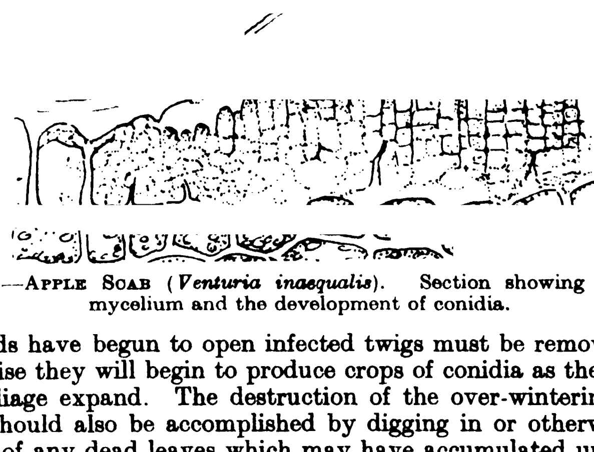


FIG. 65.—APPLE SCAB (*Venturia inaequalis*). Section showing cuticular mycelium and the development of conidia.

the buds have begun to open infected twigs must be removed, for otherwise they will begin to produce crops of conidia as the flowers and foliage expand. The destruction of the over-wintering ascus stage should also be accomplished by digging in or otherwise disposing of any dead leaves which may have accumulated under the trees. These operations, whilst enormously reducing the chances of infection, do not guarantee that it will not occur, for even if the resting stages are entirely eliminated there is always the possibility, if not the certainty, of air-borne spores coming from distant centres of infection. From the time then that the buds open until well on in the season, the actual length of time depending on the weather and local circumstances, foliage, fruit and growing twigs must be kept coated with a suitable fungicide. The usual routine is to spray the trees first of all at the "pink-bud" stage, that is before the flowers actually open, then soon after the fall of the petals, and again at an interval of about three weeks. These three sprayings are generally necessary, and in seasons when the disease is more than usually virulent yet another is advisable. If for any reason one

has to be omitted it should be the third spraying. Two fungicides are used for the control of the disease neither of which are, unfortunately, completely satisfactory. These are Bordeaux mixture and lime sulphur. The former is perhaps the more effective, though it has the disadvantage that it has to be prepared afresh for each spraying, whilst the latter can be obtained ready made and stored on the premises in anticipation of its being required. Bordeaux mixture, however, may cause scorching of the foliage and russetting of the fruit, which, in the case of a few varieties such as Cox's Orange Pippin, James Grieve, Beauty of Bath and Gladstone, may be so severe that its use is inadvisable. The difficulty may be avoided to a considerable extent by the use of a modified mixture containing an excess of lime. This is made up of four pounds of copper sulphate, twelve of freshly burnt lime and 50 gallons of water, using the same method as when preparing the ordinary mixture (p. 372). Failing this the lime sulphur wash only should be used on such scorch-susceptible varieties. Even this may damage the foliage of some varieties, such as Newton Wonder, and its use is often followed by a considerable, though not necessarily serious, increase in the amount of fruit falling in June. The normal strength is one gallon of the concentrated lime sulphur solution diluted with 29 gallons of water, but where it is to be used on varieties which are particularly sensitive to spray damage half the "summer-strength," or one gallon of the solution to 59 gallons of water, should be employed.

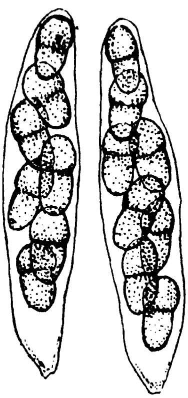


FIG. 66. — APPLE SCAB (*Venturia inaequalis*). ascus stage.

THE UREDINEAE OR RUSTS

All of the members of this large and complicated group of fungi are obligate parasites. They do not, as a rule, bring about the rapid destruction and death of the host plant's tissues, which is so characteristic of the attacks of Phytophthora or Sclerotinia for instance. In fact tissues invaded by their mycelium occasionally grow with great vigour and leaves and stems may become abnormally thickened and contorted. But the result of the invasion is always the more or less complete crippling of the host and often its premature death. This and the fact that their wide range of host plants includes some of the most important crops makes the group one of exceptional economic importance.

The life history of the rusts differs markedly from that of all other groups of fungi. The uredo-stage which, on account of its rusty-red colour has given the group its popular name, consists of thin-walled, unicellular spores with clearly defined thin patches or germ pores in their walls, through one of which the first hypha is

protruded. They germinate rapidly when conditions are favourable. The germ tubes push between the guard cells of the stomata and form a small vesicle in the intercellular spaces below from which fresh hyphæ arise. These push their way between the cells of the host plant and drive simple or branching haustoria into them. In from seven to ten days the mycelium produces a crop of uredospores which, after rupturing the epidermis, form a fresh centre for further infection. The uredo stage thus serves for the rapid dispersal of the fungus. It is followed by the teleuto-stage, consisting of thick-walled, dark coloured téleutospores which in some genera of the Uredineae are single-celled, in others bi- tri- or multi-cellular. These usually function as resting-spores. On germination they give rise to a short transversely septate basidium, each section of which produces a single basidiospore on a slender stalk. The basidiospores in turn infect their appropriate host plant by driving a germ tube through the cuticle. The host plant may be of same kind as that which produced the teleutospores or it may be of a totally different kind. For example, the teleutospores of the rust on junipers lead to the infection of pears, those of the rust on plums of anemones, and those on the sedge of gooseberries. Rusts requiring two distinct kinds of host plants to complete their life cycle on are described as heterœcious, whilst those for which a single kind is sufficient are homoiœcious. There is no obvious relationship between the hosts required by the heterœcious rusts and the elucidation of their life histories has only been effected by lucky observations or by lengthy infection experiments on every possible alternate host.

The mycelium arising from the infection by basidiospores produces aecidia. Each aecidium, when mature, is a white-frilled, cuplike structure containing chains of spores which, seen in the mass, are of a bright orange colour. The individual spores are thin-walled, single-celled, and capable of immediate germination. The mycelium they give rise to quickly produces a crop of uredospores on the same kind of host plant in the homoiœcious species, and on the alternate host in the case of the heterœcious rusts. Thus, the aecidiospores which have been produced on garden anemones give rise directly to the common rust of plum trees. The lack of the requisite alternate host breaks the life cycle of the rust, and, consequently, an obvious method of controlling their spread becomes available. Mixed with the aecidia are minute flask-shaped structures or spermogonia, from which large numbers of spermatia are exuded in a drop of sweet-smelling " nectar." The spermatia play an important part in the development of the rusts. The mycelium arising from infection by a single basidiospore forms perfect spermogonia and the rudiments of aecidia. But the complete development of the aecidia is dependent on the mingling of nectar from the spermogonia resulting from more than one infection. This is generally effected by insects. There are thus + and — or male and female strains in the rusts. Whilst all of these spore stages occur

in the majority of the rust species, the life history of some has been simplified by the omission of one or another stage. The common rust of hollyhocks and mallows (*Puccinia malvacearum*) provides an extreme example, for the teleutospore, with its accompanying basidiospore stage, is the only one produced.

The rusts attacking the cereals form the most important group of pests cultivators have to contend with. Foremost amongst these is the "black" or "stem" rust, *Puccinia graminis*. It attacks wheat, barley, oats and rye and a large number of grasses. In Europe the uredo-stage usually appears in June or early in July in the form of elongated reddish-brown pustules on the foliage, leaf-sheaths and stems, and occasionally on the ears. If the environment is favourable the spores germinate quickly and new pustules develop in from seven to ten days. As long as green shoots are available successive crops may be formed. The pustules, when about a fortnight old, often coalesce and produce elongated lesions filled with black, powdery, teleutospores. These are thick-walled, two-celled and tapering at the apex. After hibernating through the winter they form basidiospores, which produce the cluster cup or aecidial stage on the barberry which, in turn, gives rise to the rust on the cereals or grasses (Fig. 67).

The black rust cannot, however, spread indiscriminately from one cereal to another or from the grasses to the cereals. It is a composite species which includes a number of morphologically similar "biologic species," each of which is more or less rigidly confined to its own special host or group of host plants. The distinction persists even in the aecidial stage, which is common to all on the barberry, and thus, if this developed as the result of an infection from the black rust on cocksfoot, it is incapable of producing rust on wheat. The chief biologic species occurring on the cereals are :—

P. graminis Tritici on wheat. This form is not quite so sharply differentiated as those following, for it is capable of feebly infecting barley and rye.

P. graminis Avenae on oats. Whilst incapable of infecting the other cereals it can attack cocksfoot and a few other grasses.

P. graminis Secalis on rye and barley. It also occurs on couch grass and some other grasses but never on oats or wheat.

Generally speaking these species are morphologically identical with one another, and apart from their occurrence on different hosts they can only be distinguished by means of direct infection experiments.

The intensive study of the rusts which is now being made in the United States, Canada and Australia, with the object of finding ways and means of saving the cereal crops from their depredations, has shown that each of these biologic species is in turn an aggregate of biologic forms. When two similar series of wheats are inoculated with uredospores of *P. graminis tritici* obtained from two distinct sources the results are often different. Thus the rust from one source may fail to infect some of the wheats, whilst that from the

second source attacks them readily, or *vice versa*. Or again, the rust from one source may produce a heavy infection on one wheat and that from the other only a slight one. Where the experimental conditions have provided an identical environment for the duplicated series of wheats the only explanation of this phenomenon is that there is more than one sort of the wheat stem rust.

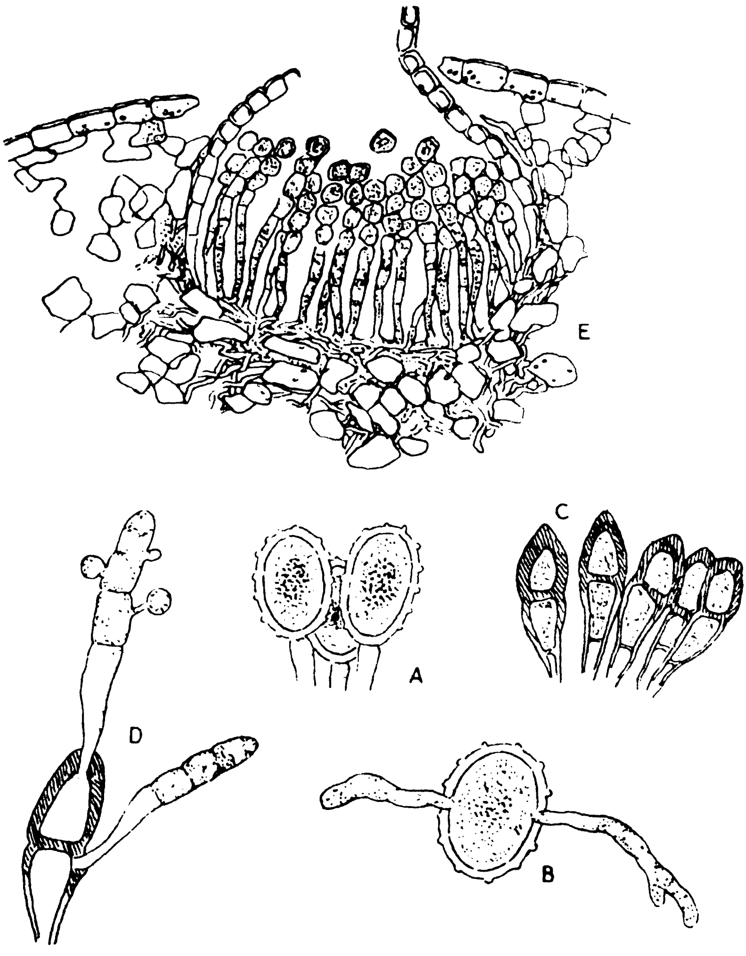


FIG. 67.—BLACK OR STEM RUST OF WHEAT (*Puccinia graminis*).

A, uredo stage.
B, germinating uredospore.
C, teleuto stage.
D, germinating teleutospore.
E, section through an aecidium showing chains of aecidiospores.

Many thousands of infection experiments, carried out on a special standard series of wheats, have fully established this fact

and led to the recognition of about one hundred distinct biologic forms. To each of these a number has been assigned. The complete identification of black rust is only possible when its behaviour on the standard wheat series has been determined, for morphological differences between the numerous forms are at the most slight and generally non-existent. The demonstration of the complex nature of the black wheat rust has led to an explanation of the puzzling phenomenon that wheats immune to its attacks in one country were often susceptible when grown in others. Their power of resistance has not broken down under the new conditions, as was often assumed, but they have been exposed to and succumbed to the attacks of a very different parasite.

The losses caused by black rust occasionally assume fabulous dimensions. Thus the Canadian crop in 1916 was only some 27,500,000 quarters as compared with the previous year's crop of 47,000,000, the difference being due almost entirely to an intense outbreak of the disease. The severity of these rust epidemics is determined mainly by climatic conditions which, even now, are none too clearly defined. In Canada their starting point is provided by a rain of wind-borne uredospores, carried by air currents, which have passed over infected crops in the United States. The date of the first infections can consequently be predicted from meteorological data. The ideal conditions for successful infection are cool nights and heavy deposits of dew in which the spores germinate freely. After infection warm and somewhat dry weather favour the development of the rust.

The control of the disease has proved to be difficult. On the small scale dusting with flowers of sulphur gives useful results, but until a technique of dusting crops from the air has been developed and wheat prices justify a greater expenditure its use cannot become general. The extermination of the alternate host, the barberry, was recommended as a means of control a century and a half before the life history of the fungus was known. It was even enforced by legislation as early as 1756 in Massachusetts. In some of the American States where the destruction of barberries has been carried out on a large scale for a long period, the main result has been to delay the appearance of the uredo-stage for some two or three weeks, when infection by wind-borne spores from districts where no such precaution has been taken has masked the value of the operation. The rust, moreover, can survive without completing its life cycle on the barberry as long as plants are available for the production of uredospores or as long as these are not killed off by adverse climatic conditions. This state of affairs obtains in Australia, where the barberry is unknown, and in the Southern United States.

The possibility of raising wheats which are resistant to the attacks of black rust are now being widely investigated. At present none of the bread wheats are resistant to a sufficiently large number of its biologic forms to be counted upon for the production of

rust-free crops. But a pronounced immunity has been found amongst the members of two other groups, namely, the macaroni wheats (*Triticum durum*) and the emmer wheats (*Triticum dicoccum*). Certain varieties of these have been found to come practically unscathed through the severest of epidemics.

After many attempts their rust-resisting power has now been built by plant-breeders into typical bread wheats, and the foundations have been laid for securing new types suitable for cultivation under various conditions. Once their cultivation can become general the menace of black rust will largely disappear.

The disease is of far more importance abroad than in this country. It was at one time very prevalent here, but for the last half century it has done little damage. In fact in some seasons it is difficult to find on wheat. When it appears it is generally too late in the season for much damage to result, except on crops which have been sown abnormally late or which have slowly recovered from the damage caused by such a pest as the wheat bulb fly.

Puccinia glumarum, the yellow rust, is the common rust on wheat in this country. Biologic species of it exist also on barley, rye, and a number of grasses. That on wheat again probably consists of a number of biologic forms. The rust is easily distinguished from the previous species by the deep cadmium yellow colour of the uredospores. The individual pustules are small and closely crowded together, often in linear patches. In severe epidemics the whole of the leaf surface may be covered with them. They occur also on the leaf sheaths, the awns where present, the glumes and also the grain. The teleutospore stage is dark grey or black in colour, and the sori lack the white frill of ruptured epidermis characteristic of those of the black rust. The teleutospores are capable of immediate germination, but up to the present all attempts to infect either wheat or any other plant with their sporidia have failed. It is possible, therefore, that the yellow rust has no aecidial stage. But as wheat is not indigenous here, the possibility remains that there is an alternate host plant in the country where it originated.

The intensity of the rust attack differs greatly from year to year. In some seasons it is so bad that the soil below the crop is coloured by the spores, whilst in others only feebly developed pustules can be found. Foliage which is heavily rusted cannot function normally, and the yield of grain consequently falls off considerably. Moreover, the grain is badly filled, and an unduly large proportion of it consists of tail wheat. The straw of badly diseased plants is discoloured, characteristically spongy in texture, and light in weight. In England crops are only exceptionally killed entirely by the rust, but attempts to grow Asiatic and Australian wheats here are often brought to nothing by the severity of its attacks.

Climatic conditions play an important part in determining the intensity of yellow rust epidemics. The development of the fungus is favoured by cool, moist weather, and in hot, dry weather it makes

little progress. In this respect it differs markedly from black rust. Soil conditions, too, have a great influence on the extent to which a crop is attacked. The fungus is always most abundant on crops growing on rich, well-farmed land, especially when nitrogenous manures have been used in an attempt to secure a large crop. Under such conditions rust is generally the limiting factor in crop production. A starved crop, on the other hand, may only show slight traces of the disease even in a rust year. The Broadbalk field at Rothamsted, with its series of differently manured wheat plots, often shows a striking lack of uniformity in the intensity of the rust attack, the unmanured controls being more or less rust free and the plots heavily dressed with nitrogenous manures orange with uredo pustules.

The starting point of epidemics in this country is almost certainly provided by the over-wintering of the uredo-stage. The uredospores remain viable for a long period under our usual climatic conditions, though a spell of hot, dry weather in the early autumn may bring about their wholesale destruction. Further, an almost continuous supply of host plants is available owing to the necessity for sowing wheat during the autumn months. A diligent search during the winter generally reveals scattered pustules on the prostrate foliage. The rust, however, makes little progress during the cold weather, and it is only exceptionally that heavy infection occurs by the end of March. More generally the epidemic begins to become severe towards the end of May, and the uredo stage then continues to develop as long as any green foliage is available. In the event of failure to over-winter, fresh infection can undoubtedly be brought about by wind-borne spores produced on rust-laden crops in France and Spain.

The only method which is available at present of avoiding losses through the attacks of rust is by growing varieties of wheat which are not markedly susceptible to its attacks. Most of those grown here show a certain measure of resistance, though they are by no means immune to rust. Rivet wheat and Little Joss are the two most resistant varieties in cultivation at present, but a heavy infection can be induced in both of these by generous applications of nitrogenous manures if the climatic conditions are favourable for the rust. A far greater power of resistance, amounting apparently to real immunity, is to be found amongst the Club wheats (*Triticum compactum*). None of these are suitable for cultivation in this country. They can, however, be crossed readily with most English wheats, and attempts are now being made to make use of the fact that resistance to yellow rust is a sharply inherited Mendelian factor to build it into wheats suitable for growing under English conditions.

The immunity of some kinds of wheat to the attacks of rust is not associated with any recognizable morphological feature. It is dependent upon some constituent of the cell sap which has a toxic effect upon the mycelium of the fungus. When uredospores

germinate on a wheat leaf the geım tubes push between the guard cells of the stomata, forming vesicles in the air spaces immediately below them. From these hyphae arise which push their way between the cells. Then haustoria are driven through the cell walls, so bringing, for the first time, the fungus into direct contact with the cell contents of its host plant. The immediate result is the death of the invaded cell and of the mycelium. In a susceptible variety, on the other hand, the penetration of the cell wall appears to have little effect on the cell itself, whilst the hyphae start away into vigorous growth. All attempts to identify the toxic material have failed up to the present.

Puccinia coronata is a not uncommon oat rust in the northern and western parts of the country. But except when infection occurs at an early stage of growth its effects are not serious. The fungus can be distinguished from the black rust of oats by the characteristic crown-like thickened processes at the apex of the teleutospores. The aecidial stage develops on the buckthorn (*Rhamnus catharticus*).

THE USTILAGINEAE OR SMUTS.

The diseases popularly known as "smuts" are caused by members of the group of fungi known as Ustilagineae. The chief species of agricultural importance form their spores (brand spores) in the ovaries of the various cereals. Some of those which attack the grasses, however, form their spores in the leaves or the leaf sheaths, whilst spore formation in some other members of the group is localized in the stamens. The brand spores may bring about infection directly, but on germination they generally give rise to either a short septate or non-septate basidium from which basidiospores are abstricted either laterally or terminally. These often fuse together in pairs. A hypha then develops which may serve to bring about infection or give rise to a spore-bearing mycelium. Though sharply confined to their particular host plants, some of the species have proved amenable to cultivation on synthetic media.

The majority of the smuts have singularly little effect on the general health of their hosts which, though infected in the seedling stages, show no symptoms of disease until the early stages of grain formation occur.

Tilletia caries is the fungus responsible for the disease of wheat known as "bunt" or "stinking smut." The brand spores develop only in the ovaries of infected plants. They are spherical in shape, with thin, dark coloured walls covered by a network of sharp-edged ridges. If placed on a moistened surface they germinate readily, giving rise to short, non-septate hyphæ, bearing at their apices a cluster of narrow, sickle-shaped spores. The whole structure is a "basidium" and the spores "basidiospores." The spores frequently fuse together in pairs and then give rise to a mycelium or possibly secondary spores (Fig. 68).

The infection of the host plant occurs only at the seedling stage. The hyphae arising from the germinating basidiospores penetrate the coleoptile and then work their way into the tissues of the stem apex. As the stem elongates the growth of the mycelium keeps pace with it, so that hyphae can always be found in the terminal growing point. When the flower rudiments begin to form it pushes its way into the tissue which would normally give rise to the ovary, and it is only exceptionally that one or two are missed to develop later into normal grains on an otherwise bunted ear. The brand spores are formed by the segmentation of these hyphae.

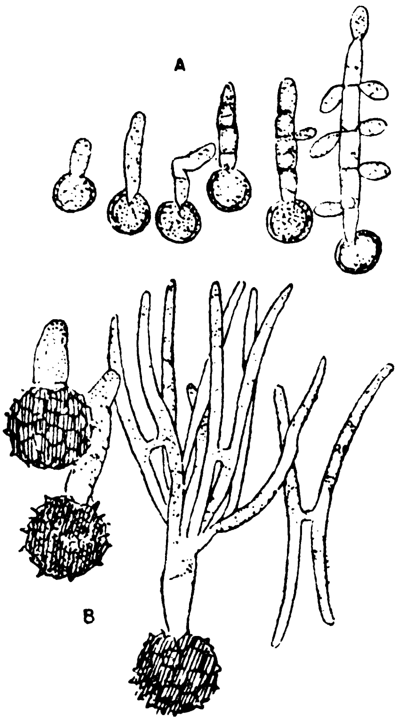


FIG. 68.

A, germinating spores of the oat smut, *Ustilago avenae* showing the development of the septate basidium and sporidia.

B, germinating spores of bunt of wheat, *Tilletia caries* with terminal, sickle-shaped sporidia some of which have fused in pairs.

The presence of the disease cannot be detected until the affected plant comes into flower. The young ears are then of a slightly darker green colour than those of normal plants, and the glumes open out a little more widely. In some forms of wheat the ear shape alters appreciably, bunted ears as a rule being laxer than healthy ones. A further symptom is afforded by the presence of small flies hovering about infected ears. The grains are deep green in colour, and, when crushed, are found to be filled with a black, greasy mass of spores which has an unmistakable fishy smell.

As the plant ripens the symptoms become less clear, and by harvest time it is often difficult to pick out infected specimens. Meanwhile the spore-containing grains mature, developing into rounded structures of a pale, rusty-grey colour. These "bunt-balls" may be broken during threshing or they may find their way uninjured into the grain. They can readily be removed by a powerful draught during winnowing. But this removal does not make the grain fit for sowing, for during the threshing operations many of the bunt balls will have been broken and the spores within them set free in the

form of a black dust. Some of this adheres to the grain, lodging particularly in the crease or in the brush of hairs at the apex. A grain sample which is heavily infected will consequently show discoloured grain tips. It will also have a characteristic fishy smell. Where the infection is slight the discolouration is so slight that it can easily be overlooked, and a careful examination may be necessary to detect it. The simplest method for conducting this is to moisten a few grains with alcohol and then add a few drops of water. The violent agitation tears away the spores, which can readily be detected on mounting a drop for microscopic observation.

Seed wheat offered for sale is very frequently contaminated with this disease * and steps should always be taken, unless there is a certainty that it is bunt-free, to disinfect it before sowing. Methods for doing so have been in use for many centuries. These involved steeping the grain in a solution of some substance which would kill the spores without injuring the grain. Foremost amongst these was a strong solution of common salt. This gave way to a steep of copper sulphate, generally used at a concentration of two per cent., which is still in use though it is rapidly being replaced by a dilute solution of formalin. One pint of formalin to 40 gallons of water is amply strong enough for the purpose. Where heavily infected grain has to be dealt with, the best method of using either of these steeps is to partially fill a wooden tub with the solution and then shoot the grain into it, stirring it about so that any bunt-balls may float to the surface. These should be skimmed off, for the fungicide does not penetrate them readily, and should they be broken a fresh infection of the grain may occur.

If, however, a careful examination has shown that no bunt-balls are present, the grain may be put into a porous receptacle, such as a wicker basket, for immersing in the solution. Twisting the basket will ensure that the surface of every grain has been thoroughly wetted. The moist grain has then to be spread on the barn floor to dry sufficiently for drilling. A still simpler method for treating slightly contaminated seed-wheat is to pour the steep, at the rate of one to one and a half gallons to the sack, over a heap of it on a clean floor, turning it repeatedly to ensure a thorough wetting. If a formalin steep is being used the heap should then be covered for a few hours with sacks soaked in the solution before the grain is dried off for sowing.

Either steep, if properly used, is very effective, and the damage it causes to the germinating capacity of the grain is negligible. The use of steeps, however, is a little troublesome, and it is in turn giving way to the use of powdered fungicides. These have the advantage that the grain can be dressed before sowing time and set aside to await favourable weather conditions. Copper compounds such as

* In 1922 33 per cent. of the samples examined at the Official Seed Testing Station contained bunt spores.

copper carbonate and copper acetate, and organic mercury compounds such as uspulun and ceresan are coming into general use. The powder is mixed with the grain, and a thorough coating is effected by agitating it in a revolving drum. This involves the use of a machine not to be found on the majority of farms. It is then a welcome sign of progress to find that some seed firms are recognizing their responsibility to their customers and offering ready-dressed seed wheat for sale. Were such seed obtained when the purchase of seed wheat becomes necessary, and were the practice of seed dressing consistently carried out, there can be little doubt that this troublesome disease could be practically exterminated. Until it is, an appreciable percentage of the crop will be destroyed each season and, what is perhaps of more importance, lower prices will be received for bunt-contaminated grain. These are entirely justified for it has to be freed from the foul-smelling taint before it can be converted into flour.

In the genus Ustilago the brand spores produce a transversely septate basidium on which are borne small rounded basidiospores. Distinct species occur on wheat, oats and barley, and there is evidence that, as in the rusts, the species are aggregates of biologic forms. The brand spores are smaller than those of bunt, their dimensions being 5—8 μ as compared with 16—22 μ.

Ustilago tritici is responsible for the particularly troublesome disease known as the "loose smut" of wheat. The symptoms differ from those of the stinking smut inasmuch as the soot-like mass of spores is set free by the breaking down of the ovary walls. This occurs at the time when unaffected plants are in full flower, and by the time that their grains have begun to swell all that remains of the ears of infected plants is the blackened rachis. No spore masses are, consequently, harvested with the crop. The small spherical wind-borne spores are caught on the feathery stigmas of the wheat flowers. They germinate directly on them giving rise to a mycelium which travels downwards into the ovary and thence into the developing embryo. In spite of the invasion, the grain develops normally, and when mature it differs in no way from an uninfected grain. The presence of the disease cannot, therefore, be detected by a simple inspection of grain samples. The infected grains germinate normally, the mycelium of the smut again growing upward with the apices of the main and lateral shoots, and forming brand spores at the flowering stage of the normal plant.

If the presence of the disease is suspected in seed wheat steps can be taken to eliminate it. Steeps like formalin or copper sulphate, which only kill superficial spores, are obviously useless. The one effective method, known after its discoverer as Jensen's method, depends upon the fact that the mycelium within the embryo can be killed at a temperature which has little or no effect upon the embryo itself. The critical temperature is from 52°—54° C. (or 125°—129° F.). The first operation is to steep the wheat in water for about four hours and then transfer it to water at a temperature of

about 45° C. It should remain in this for about ten minutes so as to be warmed sufficiently to prevent a considerable drop in the temperature when it is transferred to water at a temperature of 54° C. The temperature must be held as nearly as possible at this level by the addition, when necessary, of more hot water. After steeping for ten minutes the grain should be spread thinly on a barn floor to allow it to dry off before sowing. The process is troublesome and it requires careful supervision, for a temperature below 50° C. has little effect on the fungus and a temperature a degree or two above 54° C. leads to a considerable impairment of the germinating capacity of the grain. Though there can be no doubt about its efficacy when carefully carried out, it is generally advisable to refrain from saving seed wheat from an infected crop.

Ustilago avenae causes the very prevalent disease known as the "loose smut" of oats. The inflorescences of infected plants are usually completely destroyed at the flowering stage. As a rule the powdery, black mass of brandspores is more or less entirely blown away by the wind or washed away by rain. Some infected ovaries may, however, remain intact, and they are then harvested with the crop. The disease is spread by brandspores which have found their way on to the paleæ at flowering time or possibly during threshing. They bring about the infection of the seedling plant in the same manner as the brandspores of bunt, infection taking place with the greatest certainty at comparatively low temperatures. The presence of the disease is easily overlooked in grain samples. It can be controlled by dressing the seed corn with a dilute solution of formalin. The treatment is effective though it does not always result in a completely disease-free crop.

A second species, *Ustilago laevis* or "covered smut," is less frequent in this country.

The barley crop is also subject to the attacks of two distinct species of smut—*Ustilago hordei*, the "covered smut," and *Ustilago nuda*, the "loose smut." Both are very generally distributed. In the former the infected grains, in spite of their translucent, papery coverings, do not break up readily. They are consequently harvested with the crop, and their shattering during threshing often leads to a serious discolouration of the grain. In the latter the brandspores are set free at the flowering stage.

The covered smut is possibly the commoner form. Its life history and the method used in controlling its attacks are similar to those of *Ustilago avenae*. The loose smut, however, resembles *Ustilago tritici* in infecting the developing embryo, and the disease can only be controlled by the use of Jensen's hot water method. When employing this the temperature must be kept as closely as possible at 51° C. (124° F.). Grain from a crop which is only slightly infected should be disposed of for other than seed purposes unless this treatment can be given to it, for the disease accumulates very quickly. An almost unnoticeable infection may, unless

checked, lead to a serious loss of crop if seed is saved for two successive seasons.

HYMENOMYCETES.

Silver-Leaf Disease.—One of the diseases which has become of considerable importance of late years to fruit growers is that known as Silver-Leaf. The popular name is descriptive of one of its most important symptoms, namely, the characteristic and unmistakable silvery sheen of the foliage of infected trees. In the early stages of an attack the silvering is generally confined to a single branch. If immediate steps are not taken to deal with the disease it spreads rapidly from branch to branch. The infected branches die and ultimately the whole tree succumbs, the time elapsing between the first silvering of the foliage and the death of the tree depending on a number of factors of which the variety of the tree is probably the most important. Whilst this is the general course of disease, some cases are on record of trees making a recovery. It is not until the death of the branches that the fungus responsible for the disease, *Stereum purpureum*, becomes visible. On these, or in severe cases on the trunks of trees, the fungus develops its sporophores.

The disease occurs on a considerable number of trees belonging to the Rosaceae. Its most important host plants are plums, greengages, damsons and apples, but it has also been recorded on cherries, peaches, apricots, sloes and Portuguese laurel. Its attacks are not confined to this group of plants, however, and it has been recorded on such diverse hosts as tree lupins, laburnums, currants, gooseberries and horse chestnuts. It is, however, as a disease of the plum, and especially of one of its most generally grown varieties, the Victoria plum, that it has become of sufficient importance to warrant the compulsory application of measures for its control. The disease is now scheduled under the Destructive Insects and Pest Acts.

The first signs of the sporophores are firm, purple-coloured masses oozing out from cracks in the bark of the dead branches or tree trunks. The final form they assume is dependent on the position in which they develop. If on a more or less horizontal surface they form flat incrustations an inch or two in length, but when growing vertically a part only is attached to the bark, the remainder growing out at right angles to form a bracket-like projection about half-an-inch in width. These brackets are usually formed in considerable numbers and arranged in over-lapping tiers. The colour of the sporophores distinguishes them at once from other species of Stereum, some of which are common on dead wood. In the fresh condition the exposed face of the incrusted forms and the lower face of the bracket-like forms is a clear lavender-purple colour. It is a fugitive colour, however, and as the sporophores age they acquire a greyish buff shade. The free upper face of the brackets is densely hairy. The texture of the sporophores is tough and leathery. They are built up of densely woven hyphæ which, on

face away from the substratum, give rise to a clearly defined layer or "hymenium" of basidia, each of which bears four minute elliptical basidiospores. These spores are shed when the sporophores are in a damp condition, but as they dry up the discharge ceases, only to be renewed when they have again become swollen with moisture. Spore dispersal consequently goes on for a long period so providing the parasite with unusually good opportunities for distributing itself. The basidiospores are incapable of bringing about the direct infection of healthy tissues, and in order to initiate an attack of the disease they must come into contact with a wounded surface, such as results from the cracking of branches during picking operations, wounds formed on pruning or from any other cause. The germination of the spores and the subsequent establishment of the fungus takes place most readily on newly formed wounds. The mycelium first attacks the exposed tissues, and then invades the wood below. As it spreads through the wood its position is defined by a brown stain resulting from a gummy substance produced by the destruction of carbohydrates in the lignified walls. The discolouration provides a valuable guide when attempts are being made to prune away all of the diseased portions of a tree on which the characteristic silvering is beginning to develop. The mycelium spreads somewhat slowly in an upward and downward direction in the branches. It may work its way into the root system, and it is possible that it may even spread from tree to tree if the roots should happen to be in close contact with one another. This, however, is not of general occurrence, for in orchards the diseased trees are usually scattered at irregular intervals rather than occurring in groups, as they would if this mode of transference were the rule. The fact that the mycelium may be found in the root system has, nevertheless to be borne in mind when considering methods of controlling the disease. It does not extend into the foliage, so that silvering cannot be accounted for by the direct action of its hyphae

A

FIG. 69.

Silver leaf disease (*Stereum purpureum*); sporophores on branches of Victoria plum.
A, the more or less bracket-like, and B, the resupinate forms.

on the leaf tissues. The symptom is the result of the separation of the cells of the leaf one from the other and the formation of air spaces between them, especially in the palisade layer. This has much the same effect as a crack in a piece of thick glass, which shows up as a white line only when it is filled with air. Secretions of the fungus travelling to the leaves from the infected wood are responsible for it, for if cultures of the fungus are grown on suitable media and sterile watery extracts of them injected into a healthy branch the symptom soon appears.

The fungus may fail to establish itself successfully, and when infection occurs in the summer months the tree may be the victor in the struggle between host and parasite. Its mode of defence, apparently available only at this period, is to stop the spread of the mycelium by the formation of an impassable barrier of dense gum. This same blocking procedure probably accounts for the occasional recovery of slightly infected trees. Different varieties of plums differ amongst themselves in their defensive capacity.

From time to time methods for curing infected trees have been suggested. Amongst these are nails driven into the trunks, augur holes plugged with ferrous sulphate, or dressing the soil with this material, but at present no reliable cure has been discovered. Checking the spread of the disease is, however, a comparatively easy matter. The most radical method is to uproot and burn the trees as soon as the first symptoms are detected. This, though a sound policy, is often unnecessarily drastic, for the extension of the disease, if taken in time, can be definitely prevented by cutting out the infected portions. In carrying out this operation the silvered branch must be cut back to a point at which no brown stain is visible in the wood. Where the silvering is general the mycelium has probably reached the main trunk, and nothing can be done to save the tree. A common practice in the past has been to stub it back to the trunk and then top-graft it, but the almost inevitable result is that the scions speedily become infected.

Infection may be largely prevented by care in the management of the trees. The essential point is to avoid as far as is possible the formation of the wounds necessary for its occurrence. Such wounds are often the result of heavy crops of fruit breaking unsupported branches, or of the splitting of forks at picking time, or damage done to trunks and low set branches during cultivation. They are also produced on the removal of surplus branches and during pruning. The latter operation, though of little importance in established orchards, has to be carried out in nurseries when the stocks are cut away from the established scions and again when the foundation branches of the young trees are being formed. All such wounds should be dressed as soon as possible with a protectory coating on which the spores will not germinate or, if they succeed in doing so, through which the resulting hyphae cannot penetrate. The material most generally used for the purpose is either Stockholm or gas tar. Coatings of either of these require to be

frequently renewed to be effective, and trouble can be saved and more reliable protection secured by the use of a thick-bodied paint.

In addition to these obvious protective measures, steps should be taken to prevent the development and distribution of basidiospores. As the sporophores form only on the dead wood it should be cut out as soon as practicable, and if the whole tree is either evidently moribund or dead it should be grubbed out and the main roots at least extracted. This wood should be destroyed by burning at once. The practice is far too common of setting aside the larger pieces for firewood, stakes, etc., whilst the smaller branches have been made use of for such purposes as stopping gaps in hedges.

Better procedures for growing crops of sporophores could hardly be devised, for the fungus continues to live saprophytically and grows apparently as vigorously as when associated with a living tree. If these preventive operations are carried out thoroughly, *Stereum purpureum* can be completely eradicated from infected orchards and further outbreaks of the silver-leaf disease largely prevented. But the possibilities of fresh centres of infection being available locally must always be borne in mind. As far as is known at present, there is only one form of the fungus on the various host plants on which it is known to exist. Thus the assumption should be made that the disease may spread from an infected blackthorn in the orchard hedgerow or from a nearby laburnum, and these in turn should find their way to the bonfire.

In planting new plum orchards, especially in the vicinity of town gardens in which the disease is still too prevalent, it is a sound policy, where practicable, to make use of the more resistant varieties. The accumulated experience of growers has now made it clear that two of the most popular varieties, Victoria and Czar, are unfortunately especially liable to silver-leaf. The yellow Pershore plum, River's Early Prolific and Blaisdon Red, on the other hand, are comparatively rarely attacked, whilst a moderate degree of resistance is shown by Monarch, Pond's Seedling and the Purple egg-plum.

The Silver-leaf Order of 1923, made under the Destructive Insects and Pests Acts, requires the cutting out and destruction by fire of all dead wood on both plum and apple trees before the 15th July of every year. Further, if the trees have died, their complete grubbing out and immediate burning is insisted on. The order is based on a knowledge of the life history of the causative fungus, and its steady enforcement, with the willing co-operation of growers, has done much to check the spread of the disease in commercial plantations. But where these precautions have been neglected, as is commonly the case in the small gardens of towns, the disease is rampant. The death of the infected trees should, however, soon result in its disappearance.

Merulius lacrymans.—The higher forms of the Basidiomycetes are characterized by the development of more complex sporophores than those of Stereum, but they are, nevertheless, still built up of

a solid mass of practically undifferentiated mycelium. A relatively simple type is represented by *Merulius lacrymans*, a species known under various names, such as "dry-rot," the "weeping fungus" or, in Germany, as the "house fungus." Its popular names, though at first sight rather contradictory, briefly sum up its more obvious characteristics. The sporophore forms an incrustation resembling that of Stereum, but the exposed face is covered with folds and wrinkles, forming a series of shallow pits the surfaces of which are lined with basidia.

The fungus is comparatively rare in the open but it is commonly met with in farm houses and farm buildings, where its destructive effects are well known. In any moist situation such as in cellars or in the space between the soil and a floor, it develops a vigorous mycelium in the form of a dense, white, felt-like sheets which can readily be stripped off of the joists or floor boards. As this grows thick strands of hyphae packed with nutrient material and capable of transporting water, are formed. These often grow to great lengths, not only on wood but also on the surface of brick walls, etc. As a consequence, wood far removed from the original source of infection may become attacked, and an outbreak at soil level may ultimately have serious consequences to the roof timbers. The sporophores are six inches or so across and of a rusty-brown colour when mature. They produce such enormous quantities of spores that the first symptom of the presence of the fungus, apart from its characteristic mouldy smell, is the accumulation of a rust-coloured dust on floors, shelves and furniture. There are said to be some 65,000 millions of these in a cubic inch of the dust. When the spore formation stage has been reached the wood is usually so badly attacked that the next symptom is the sagging of beams or the collapse of the floor boards. The spores germinate readily on a moist substratum of wood and quickly give rise to the mycelial sheets. The hyphae of these permeate the wood, partially destroy the lignified cell walls, and reduce it to a spongy, brownish mass which readily absorbs and retains water. When dry the decayed portions shrink and crack, and the fissures forming at right angles to one another divide it into cubical blocks which can easily be rubbed down into a powder.

Where an outbreak occurs it should be dealt with immediately. Every piece of wood which has been reached by the mycelium should be cut out and replaced with sound timber which has been thoroughly brushed over with a solution of corrosive sublimate or creosote. Then it is essential that steps should be taken to prevent a further attack. As the growth of the fungus is dependent on a supply of moisture, an endeavour should be made to trace this to its source and prevent its further access. This is often revealed whilst the decaying wood is being replaced. One of the commonest points of entry, especially in old buildings where damp courses are non-existent or inefficient, will be found to be joists let into walls at or below the soil level. An external surface drain will do much

to keep such a wall dry, and the liberal use of creosote, both on it and on the end of the joists inserted in it, should stop any fresh infection. Then provision should be made for a thorough ventilation of the space enclosed between the ground and the floor boards.

Polyporaceae.—In the Polyporaceæ the sporophores are fleshy, leathery or woody in texture, and they usually grow in the form of bracket-like structures standing out at right angles from tree trunks. On their lower surface is a layer, capable of being detached from the rest of the sporophore, which is built up of coherent tubes lined with basidia. The mycelium is confined to the wood, which in time is usually reduced by its action to powdery touchwood. Some of the most serious diseases of forest trees and hedgerow timber are caused by their attacks, but apart from a few species occurring on fruit trees they are of no great importance to agriculturists. The following occur frequently in old orchards :—*Fomes pomaceus* on plum trees, especially on the variety Pershore ; the sporophores are from one to two inches across, hoof-shaped, rusty brown and finally black in colour. *Polyporus adustus* on apples : sporophores brown-grey to black in colour, zoned. *P. hispidus* on apples : sporophores chestnut colour above and lemon-yellow below, becoming dark brown as they age ; from four to ten inches across. No satisfactory methods for the control of these wound parasites has yet been devised.

Agaricales.—In this group the basidia are formed on gill-like plates radiating from a common centre. The common mushroom is a fairly representative type of this great group of fungi. Practically all of them are saprophytes, one of the few exceptions being the honey or shoe-string fungus which is commonly found on all kinds of trees and is occasionally a troublesome pest in gardens, orchards and plantations of gooseberries. The mushroom-shaped sporophores are formed in large clusters at the base of infected trees or on stumps which have been left in the ground. They are honey-yellow in colour and the top of the cap bears many dark brown fibrous scales. Though specimens vary much in colour and size, they are always recognizable at a glance. The white basidiospores can readily be seen by cutting out the stalk of a sporophore and placing it gill side downwards on a sheet of coloured paper covered with a tumbler to exclude draughts. As they rain down they form a perfect print of the gills. Similar spore prints are often seen on the caps of sporophores overlapped by their neighbours.

If the bark of an infected tree is stripped off anastomosing strands, or rhizomorphs, not unlike leather bootlaces, will be found on the surface of the wood. These pass over in their younger portions to delicate white sheets of mycelium, the hyphae of which penetrate and destroy the tissues of the wood. They also spread through the soil, travelling for considerable distances at a depth of about four inches. On coming into contact with a sound root, their hyphae penetrate between the crevices of its bark and develop

rapidly between it and the wood. The disease thus tends to spread centrifugally. Its effects on the tree are characteristic. Once the roots have become infected and the mycelium has worked its way round the base of the tree, it dies suddenly. The disease is difficult to control. Cutting down infected trees is of little use since the fungus can grow as a saprophyte on their stumps, and even if they are uprooted rhizomorphs may still be left in the soil. An open trench, across which they cannot pass, will, however, prevent their extension. Where the disease has to be dealt with in gooseberry plantations it can be completely eliminated by digging out infected specimens as soon as symptoms of the attack are noticed.

FIG. 70.
Rhizomorphs of the honey or shoestring fungus, *Armillaria mellea* growing between the bark and wood of an elm.

BACTERIA.

The bacteria are a group of unicellular organisms resembling the fungi in their mode of nutrition but differing from them in their method of growth. They are exceedingly minute, the largest of them seldom being more than ten thousandths of a millimetre in length. Their shape may be that of spheres, long or short rods, commas or corkscrews. Multiplication is effected by the simple division of the individuals into halves, the new ones so formed either becoming separate or remaining united in chains, sheets or solid masses when the divisions take place in one, two or three planes respectively. The successive splittings follow with great rapidity, and a single cell may become two in twenty minutes after its formation if the conditions for growth are favourable. Reproduction may also be effected by means of spores formed either internally or by the thickening of the cell wall. The spores are highly resistant to extremes of temperature and to drought, and consequently they provide the bacteria capable of forming them with a resting stage. Many species are motile owing to the presence of one or more cilia.

It is difficult to realize the great importance of the group to mankind. They are mainly responsible for the decomposition of the organic matter built up by plants and animals. To counteract this, in the case of materials required as food, various processes of preservation, such as cold storage, canning, bottling, dessication, pickling, and so on, have had to be devised. They play a great part in the manufacture of various dairy products, in which their

activity is often brought under control by sterilizing, with the object of destroying unwanted species, or by the addition of pure cultures of those known to produce the required results. In the soil and manure heaps their development determines the production, or in some cases the destruction, of essential nitrogenous plant food materials, as well as the reduction of cellulose-containing tissues to humus. They are, however, better known generally as the causative organisms of many diseases, such as typhoid, cholera, tuberculosis and diphtheria. Plants are also attacked by them and a number of diseases, fortunately of no great importance agriculturally, have been traced to them. On the other hand the peculiar association of bacteria and leguminous plants, hardly to be described as a disease, is a matter of great economic significance.

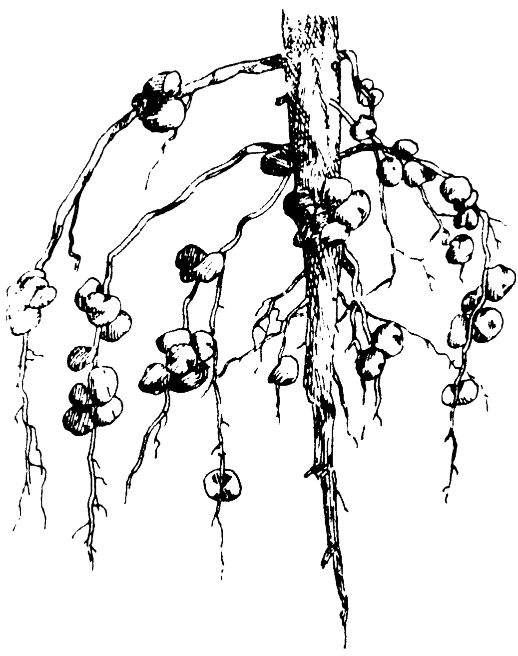


FIG. 71.- NODULES ON THE ROOTS OF A SOYA BEAN.

The Nodules of Leguminous Plants.—The clovers and leguminous plants in general have been described as " nitrogen-accumulators " because their tissues contain, mostly in the form of proteins, an unusually large percentage of nitrogen. This is evident when a comparison is made of the average total nitrogen percentage in the seeds of a number of the cereals and of the pulses :—

Maize	1·8 per cent.	Peas	4·3 per cent.
Buckwheat ...	1·9 ,,	Beans	4·6 ,,
Oats	1·9 ,,	Lentils	4·7 ,,
Wheat	2·3 ,,	Soya beans	6·1 ,,

Moreover, these plants can build up the large quantities of protein represented by these figures when growing on soil deficient in nitrogenous food materials. In fact, crops such as lupins can be grown satisfactorily on sandy soils incapable of carrying any non-leguminous crop, and their growth actually enriches the soil sufficiently for it to be used as a method for bringing such land under general cultivation. The value, too, of the nitrogen-collecting clover as a preparation for the wheat crop has been realized for several centuries.

If the seeds of a leguminous plant are sown in sand to which all of the essential elements, except nitrogen, have been added, the resulting plants grow normally until the reserves of food stored in their cotyledons are exhausted. Growth then ceases, the leaves become yellow, and they look as if they would die. Any other kind of plant under such conditions would soon perish through nitrogen starvation, but leguminous plants suffer a temporary check only, and almost suddenly recover and grow away normally. The root system of these plants differs from that of all other agricultural plants in bearing numbers of nodules on the main and lateral roots (Fig. 71). These begin to develop at an early stage of growth, and reach a size varying from that of a small pin's head to that of a pea, or even greater. Further, they fail to form when the plants are raised under completely sterile conditions, but their development can then be induced by the addition of traces of freshly crushed nodules to the soil or other medium in which the plants are rooting.

Sections cut through fresh nodules show that they have the usual structure of roots but that the pith is more strongly developed and of a pale red or greenish-grey colour instead of white. Appropriate staining methods show that the cells composing it are crowded with somewhat irregularly shaped bacteria (Fig. 72). These can be isolated from young nodules and cultivated on suitable, artificial media. Cultures from different species of leguminous plants show differences which suggest that a number of distinct strains of the organism *Pseudomonas radicicola* exist. This view is supported by the fact that the bacteria isolated from peas fail to produce nodules on lupins or red clover.

The nodule-forming organisms are generally present in agricultural soils, so that when a leguminous crop is sown its roots soon become infected and, generally speaking, the more abundantly the nodules are formed the better the crop grows. Exceptions occur, however. The organism responsible for their formation on the roots of lucerne has not the wide distribution of that occurring on the roots of red clover, and where it is lacking the establishment of a lucerne crop is impossible. This probably accounts to a certain extent for the limited area under this crop. Again, the form responsible for nodule formation on the roots of the Soya bean is apparently lacking in the soils of this country. Such deficiencies can readily be done away with by inoculating the soil with the

appropriate form. This can be done by scattering a few sacks of soil, taken from a field on which the crop is known to thrive, over the surface. The nodules on the Soya bean root (Fig. 71) were induced to grow in this manner, the material used for inoculating a plot being soil specially imported from a Japanese bean field. The general practice nowadays, though, is to use cultures of the required organism. When, for instance, lucerne is to be grown on a soil which has not carried the crop previously, especially in a district where it is not already in cultivation, a culture of the lucerne nodule organism is purchased, diluted down according to the instructions provided with it and then poured over the seed. The essential organism thus finds its way into the soil ; it then infects the root hairs of the young plants directly, and quickly gives rise to a crop of nodules. The growth of the bacteria in the tissue of the host plant is dependent on the supply of carbohydrates which they can obtain from it. Utilizing this material as a source of energy, they build up nitrogenous food stuffs directly from the inert atmospheric nitrogen which, on their death, become available for the use of the host plant. Host and invading organism are thus essential to one another. Such a relationship, so strikingly different to the types previously described, is known as "symbiosis."

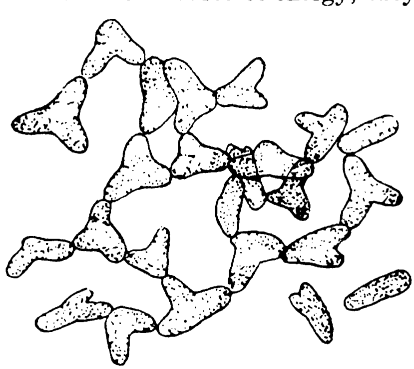


FIG. 72.—ROOT NODULE ORGANISM (*Bacillus* (*Pseudomonas*) *radicicola*).

VIRUS DISEASES.

The maladies of plants which have so far been described are all traceable to the fact that they have become the hosts of easily recognizable parasitic fungi. There is, however, an important group of diseases, known as "virus diseases," which are characterized by the fact that the most thorough microscopic examination has failed to detect any organism in the tissues of the infected plants. Moreover the attacks are not localized, as they are in the majority of the diseases produced by fungi, but they extend throughout the plant. Thus no part of it can be used for vegetative propagation in order to secure a disease-free specimen. Thus if a potato plant was attacked by the organism responsible for wart disease, healthy plants could be raised from it by striking cuttings of the haulm, or planting any tubers which happened to show no symptoms. But if infected with a virus disease, such as "mosaic," either procedure would invariably result in the growth of similarly diseased specimens. The infection may, in some cases at least, even be transmitted by seed.

The existence of virus diseases is not a new discovery, but it is

only within recent years that systematic attempts have been made to investigate them. One, the "curl" of the potato, was well known over a century ago when it was so troublesome that the growers found it necessary to test their stocks of seed tubers before planting them by sprouting in warm frames. Since then about a hundred of these diseases have been described. Amongst those of economic importance are several occurring on the potato and others on sugar cane, maize, sugar beet, tobacco, cucumbers, hops and raspberries. Their attacks are not confined to the plant world for a number of important animal diseases, including foot and mouth and swine fever, are caused by them.

The symptoms associated with virus diseases are often slight and difficult to define. In some cases, indeed, an infected plant may show none at all. It then acts as a "carrier" in much the same way as an individual who may carry and spread typhoid fever without being obviously the worse for being infected with it. Some of them are a thickening and rolling of the leaves, often accompanied by changes of colour, mottling and crinkling, discolouration of the veins, faint concentric markings around a central spot, a general dwarfing and, in extreme cases, lesions, which may be followed by the death of the leaves or even of whole branches. The study of the symptoms is of particular importance in this group of maladies because, apart from actual infection experiments, it is the only way of diagnosing the disease. Those of a number of the commoner diseases have now been sufficiently defined to make their recognition generally possible, and the most pronounced of them are frequently used for popular descriptive purposes, *e.g.*, "streak," "crinkly dwarf" of potatoes, "mosaic" of hops, etc.

Owing to the lack of visible characters their properties only can be used in defining the viruses. The most important of these is that the diseases they give rise to are extremely infectious. The mere rubbing of a leaf from an infected plant on to that of a sound one is sufficient to transfer some virus diseases. Many can be transferred by scratching the leaf of a healthy plant with a needle point previously used to puncture one carrying the disease. Those incapable of being spread in this manner can usually be transferred by grafting portions of diseased on to healthy plants. The method is largely employed in laboratory investigations. In nature juice-sucking aphides and similar insects are the effective agents in spreading many virus diseases, a fact which suggests that their dissemination might often be controlled by the use of appropriate insecticides.

As might be anticipated from the foregoing, the sap expressed from an infected plant contains the virus. This material is used in investigating the properties of different kinds of viruses. Whilst the expressed juices differ much amongst themselves they have a number of common features. One of the most characteristic is that filtration through unglazed porcelain has no effect on its infective capacity. As such filters effectively prevent the passage of

bacteria, it is not surprising that the microscope has failed to reveal any organism associated with virus diseases. The infective capacity of the juice may be retained for long periods if it is simply stored under conditions preventing the growth of bacteria and moulds, or even if it is dried over sulphuric acid. That from diseased tobacco is said to be capable of "living" for years, whilst at the other extreme are viruses which "die" after a few days. Heat destroys their power of bringing about infection, a temperature of about 80° C. being generally sufficient for this purpose. The extracted juices can be greatly diluted with water, and in some cases an attenuation of one in 10,000 has not been sufficient to destroy their powers of infection. The general resemblance of their properties to those of enzymes, such as diastase, is noticeable, but though some are said to be precipitable by ammonium sulphate, none have yet been satisfactorily isolated. On the other hand, all attempts at their cultivation outside of the tissues of their hosts have been failures.

Some of the best known virus diseases are those associated with the potato. One of the commonest of these is that known as "mosaic," which is so prevalent that it is estimated that 90 per cent. of the stocks of potatoes in the country are infected by it. The symptoms, which in some seasons are not particularly obvious, are a mottling of the foliage, often accompanied by a slight pitting of its surface. "Crinkle" is also characterized by mottling and the leaf surface is distorted and its margins waved. In "leaf-roll" the foliage is at first pale in colour; the leaves then roll from the base upwards so as to hide their upper surfaces. These, and still other virus diseases, cause a marked diminution of the yielding capacity of potatoes, and they are also responsible for the running out and the increasing susceptibility to blight of many of the older varieties (p. 163).

The dissemination of these diseases is dependent on insect agency. The insect fauna of the crop is a considerable one, but of all the insects which have been used experimentally in transmission experiments the only one which has proved to be capable of transmitting them is the aphis *Myzus persicae*. Even other species of aphides, as well as capsid bugs and leaf-hoppers, appear to be powerless to do so. Leaf roll, which is not transmissable by means of a needle, is easily transferred by it. The new infections cannot, therefore, be due to a mere mechanical transfer of the virus, and experiments indicate that an incubation period in the body of the insect of about two days is necessary before the material taken from the diseased plant can become infective.

The diseases are also spread whilst the tubers are in store, and especially when placed in trays for sprouting. Under such conditions the aphis is not uncommon on the young shoots and may easily transfer the virus from infected to sound tubers. In other directions man's contribution to the spread of the disease is a great one. The almost invariable practice in planting is to make use of

small sets, and it so happens that one of the characteristic features of a diseased plant is their production. The tendency, therefore, is towards the automatic selection of virus-sodden tubers as a starting point for the next crop.

For further information on the subject of disease in plants the following books should be consulted :—

Collected Leaflets on Fungus Diseases of Fruit Trees. Ministry of Agriculture and Fisheries. London, 1929.

Plant Diseases. By F. T. Brooks. Oxford University Press, 1928.

The Scientific Principles of Plant Protection. By H. Martin. E. Arnold & Co. London, 1928.

CHAPTER XVII.

THE PRINCIPLES OF PLANT AND ANIMAL BREEDING.

THE many good qualities, and the diversity, of our present day breeds of domesticated animals and plants are chiefly due to the efforts, of one sort or another, which have been made to improve them from the earliest times. But with greater skill and knowledge, and higher standards of agricultural practice, there can be no doubt that improvement has been far more rapid during the last few hundred years than it was at most times in the past. In Great Britain, from the time of Bakewell, the number and value of our breeds of livestock have been greatly increased by methods which are fairly widely understood in the agricultural community, and usually demand art and skill rather than scientific knowledge. Starting with a clear vision of what is to be aimed at, the guiding principles are first a rigorous selection of the few individuals that are nearest the ideal ; and perhaps in the early stages fixation by inbreeding. Secondly, if necessary, the introduction of a desirable quality by crossing with a different breed, which was possibly imported from abroad and may have been only distantly related to the original breed.

In broad outline, the principles of plant breeding are similar ; but their application has to be adapted in each case to the particular method of reproduction of the plant concerned. Thus, many crop plants are reproduced vegetatively, and a single plant with valuable features can be divided up to form a new variety, of which all the individual members will be identical. That is to say, once the desired type is obtained, whatever the means, the problem of fixing it does not arise. But with plants that are reproduced by seed the problem is twofold. First the desired type must be produced. and secondly it must be ensured that it will come true from seed when it has been produced. The second task will need different methods when the plant dealt with is self-fertilized and when it is cross-fertilized, since in the latter event it will be crossed by other individuals which will probably be different from itself.

The great complexity of the situation in plants requires more specialized methods of breeding, so that scientific principles have been applied with more immediate success. These principles can be illustrated most easily if the simplest case is taken first, namely that of self-fertilized plants. Observation shows that such plants may breed quite true to type. If the produce of a single plant is sown separately all the offspring will be exactly alike as far as can be seen, apart from minor differences in characters such as height and vigour. These differences are caused by accidental circumstances, such as one plant having rather more room than another or standing on a slightly richer piece of soil, and so on. That this is so can be tested by sowing the seeds of each plant separately again in small plots. In each plot there may be a hundred or so plants; and not only will all the plants within each plot look alike, but each plot will be exactly like the next, again except for slight inequalities due to soil differences. That is to say that when the progeny of the original plant was grown it was found they were all alike except that some were rather more robust or fruitful than others. The suspicion that this might be accidental is confirmed because the plot raised from the seeds of the most robust plant is no better than that raised from the least robust.

This conclusion is important because it means that a self-fertilized plant can come perfectly true from seed, and that selection amongst its progeny will have no effect at all. Whether the seeds of the best plant or of the worst are taken makes no difference, unless the seed of the worst plant is so poor that the progeny have a bad start. The descendants of such a true breeding self-fertilized plant are said to form a "pure line," and selection within a pure line is ineffective. The minor differences that we find within a pure line, caused by the accident of position, are called "fluctuation." Fluctuation is seen most easily in measurable characters such as height or yield, but it may affect other characters as well. The depth of colour of a red-eared wheat may fluctuate because some ears have received more sun than others; while the late tillers of an awned barley may have awns of different length from the early tillers, because they developed under somewhat different conditions. But these differences will not be carried on to the next generation.

If the observations on self-fertilized crops—such as wheat, barley, or beans—are continued, it will be found that most commercial varieties are not pure lines but mixtures of closely similar pure lines. If the stock examined is not very good it may even be possible to pick out different lines by eye. If it is a better one, all the plants may look the same except for a few "rogues"; but if the progeny of individual plants is grown on in separate plots small differences between the plots will be detected: one plot may be a little taller than another, or may have rather heavier seeds. If this selection of single plants is continued for another generation it will have no result. The first selection was successful because the commercial variety was not a pure line; but selection isolates these different lines at

once and, as soon as they are isolated, further selection has no effect.

The experiment just described was first carried out by Johannsen, who published his conclusions in 1903. He used a commercial variety of the runner bean, *Phaseolus vulgaris*. Some plants were selected and their progeny grown separately in different rows. The seeds of every plant, from each row, were weighed, and the average seed weight was found to be different in different rows, varying from 3.51 grammes to 6.42 grammes. Selection was continued by growing separately the lightest and the heaviest seeds from within each row. But after several generations no further change could be detected. The first selection had isolated the different lines, and after this it made no difference whether the lightest or the heaviest seeds of any one line were chosen; the mean weight remained constant at about 3.5 grammes for the lightest and 6.4 grammes for the heaviest line, only varying slightly from season to season.

The pure line principle suggests at once that varieties can be improved simply by selection from commercial stocks. The latter consist of mixtures of lines, of which some will give better results on a given soil and in a given climate than others. As a general rule the best result will be obtained by choosing only the best of these lines; and, by so doing there will be the added advantage of securing complete uniformity, which ensures that the stock will always remain the same. This has a special value in crops such as barley, wherein uniformity is itself an important feature. But it should be remembered that the line which has been selected, while the best for some soils and districts, may not be the best for others, for which different lines may be more suitable.

Agricultural practice has often been in advance of scientific principle, and this method of breeding was first practised by Le Couteur of Jersey as long ago as 1832, nearly 100 years before the pure line principle was discovered. He was first led to adopt the method after showing his crops to La Gasca, a Spanish professor of botany who had made a special study of wheat. In his own words he says, "I considered my crops as pure, at least as unmixed, as those of my neighbours, when to my dismay he drew from the fields three and twenty sorts. Some were white, some red, some liver-coloured, some spring-wheat, some dead ripe, the corn shaking out, some ripe, some half so, some in a milky state, and some green. I reflected on the subject, and immediately became convinced that no crop in that state could either produce the greatest weight of corn, give the largest quantity of flour, or make the best or lightest bread, such as would be produced from a field in an equal and perfect state of ripeness." He therefore selected those ears that looked alike and grew them together as separate varieties, but found this not enough. "The care I took in making these selections, and the great number of sorts I found of all shades and colours, forming varieties and sub-varieties, as they are named by Professor La Gasca, confirmed my conviction that the only chance of having

pure sorts was to raise them from single grains or single ears. It is but fair to add that even the pains I took in making these first selections amply rewarded my labours, as the produce of my crops was increased from an average of about 23 or 25 bushels an acre to about 34, and since I have raised wheat from single ears of carefully selected sorts, I have increased my crops to between 40 and 50 bushels the acre."

If the pure line principle shows how varieties can be improved by selection it also shows the limitations of the method. Once the best pure lines have been isolated nothing more can be done by selection alone. To go further new lines must be created ; and this is done by crossing. We may find that our best lines of wheat stand and yield well but are rather susceptible to disease—to rust for example. At the same time there may be another line, inferior to the first in yield but resistant to rust. If we could transfer this resistance to the first variety we might increase its yield still further, by reducing the toll taken by rust. This method of improvement by crossing is a modern development and is carried out more easily with a knowledge of the laws of heredity discovered by Mendel ; though it was, in fact, used with success in different parts of the world before Mendel's principles were generally known.

The principles in question were discovered by Mendel in 1866, but they were not appreciated at the time, and remained neglected until 1900, when they were rediscovered by three botanists—de Vries, Correns, and Tschermak—simultaneously. At this period their importance was realized at once ; and they now form the basis of the science of genetics—the study of heredity and variation—which has grown rapidly in recent years. Mendel began his experiments with the edible pea, *Pisum sativum*, which is self-fertilized. He crossed a plant from a tall strain, 6ft. high, with another plant from a dwarf strain, 1 ft. high. The tall plant came from a strain that had always bred true to tallness. When such a plant is self-fertilized the seeds are formed from the union between an egg-cell carrying something, T, which produces tallness, and a male gamete also carrying T. These seeds can therefore be denoted TT, and when they are sown they will give plants which are tall like the parent plant. Similarly, all the plants in the dwarf strain can be denoted DD. TT and DD plants give only T and D, respectively, to their egg-cells and pollen grains, so when they are crossed together they will give a hybrid—the "F_1" as it is usually called—which will be TD ; and it will be TD whether we use the tall plant as female parent and the dwarf as male, or whether we make the reciprocal cross by using the dwarf as female and the tall as male. Having obtained the F_1 plants, which will all be alike, we can raise a further generation—the "F_2"—by self fertilizing the F_1. It will be found that the F_2 consists of tall plants, like the tall parent, and dwarf plants, like the dwarf parent, in the proportion 3 tall : 1 dwarf. To understand how this happens we must see how the seeds borne by the F_1 plant are produced.

Since the F_1 is TD it can transmit either T or D to its egg-cells and pollen grains; and we will suppose that they will be transmitted in equal proportions, *i.e.* in the ratio 1 T : 1 D. Each T egg-cell can be fertilized either by a T or by a D male gamete; and since either is equally likely to happen, all the T egg-cells together will produce on the average TT seeds and TD seeds in the proportion 1 TT : 1 TD, the first by fertilization with T male gametes and the second by fertilization with D male gametes. Similarly, the D egg-cells can be fertilized by T or by D male gametes; and will give on the average TD and DD seeds in the proportion 1 TD : 1 DD. All the F_1 egg-cells together will therefore give the following seeds: 1 TT + 1 TD + 1 TD + 1 DD. That is to say the proportion will be on the average 1 TT : 2 TD : 1 DD. When these seeds are sown they give the F_2 generation, which will consist of three different kinds of plant occurring in definite proportions, if enough seeds are sown, namely:

1 TT—exactly like the tall parent, breeding true to tall;
2 TD—tall like the F_1, not breeding true but splitting up like the F_1 into tall and dwarf;
1 DD—dwarf, like the dwarf parent, breeding true to dwarf.

T, which produces the tall character, is spoken of as the "factor" for tallness; and D as the factor for dwarfness. The separation of T and D in the F_1, so that the reproductive cells contain either T or D but not both, is spoken of as "segregation"; and the two factors T and D which segregate from one another are said to be a pair of "allelomorphs." A plant such as TT or DD, which contains two factors of the same kind is called a "homozygote"; TT and DD are homozygous for T and D respectively. TD, containing both allelomorphs, is said to be a "heterozygote" or to be heterozygous for T or D. In the particular case we have described the heterozygote, TD, is exactly like the homozygous tall, TT, in appearance; and in such a case tall is said to be "dominant" to dwarf, the "recessive." The recessive is usually denoted by a small letter instead of a capital, thus T = tall. and t = dwarf.

It is important to notice that in F_2 or later generations the homozygous tall segregates are as tall as the tall parent, and the dwarf segregates as dwarf as the dwarf parent. This means that when T and D are present together in the F_1 they have no effect on each other, but segregate from one another completely unchanged; so that the gametes contain T exactly like the original T, and D exactly like the original D.

The ratio found in F_2 was 1 TT : 2 Tt : 1 tt, and in the case dealt with, in which tall is dominant, the plants would be classified by eye as 3 tall : 1 dwarf. All the recessives breed true but only one-third of the talls, the remaining two-thirds being heterozygotes which split up again to give a 3 : 1 ratio like the F_1. In other cases, the F_1 and F_2 heterozygotes may be intermediate between the two parents in appearance. Thus in some species of plants with coloured flowers, the cross red × white gives a pink flowered F_1, and a ratio

of 1 red : 2 pink : 1 white in F_2. In practice it is evidently a great advantage to be able to pick out each of the three different kinds of plant, knowing how it will breed, instead of having to test by breeding whether it is a pure dominant or a heterozygous dominant.

It will be understood that the ratios 3 : 1 or 1 : 2 : 1 are only average ratios which will be obtained if a sufficiently large F_2 is grown. If we only had four plants it would not be very likely that three of them would be tall and one dwarf; indeed, it would be quite possible, though not very probable, that we had picked out four dwarfs or four homozygous dominants. It is only when a reasonably large F_2 is counted that we shall find a close approximation to the 3 : 1 ratio. In actual experiments the numbers 96 : 29, 51 : 18, 9 : 3, 14 : 3, and 607 : 197 have been obtained. Large scale experiments have given the ratio 23,531 : 7,847 = 2·9997 : 1·0003 for the characters starchy and sweet endosperm in maize.

All kinds of characters, in many different species of plants and animals, are inherited in the same simple manner we have described. As examples we may give hairy or smooth chaff, and susceptibility or resistance to rust, in wheat; six row or two row in barley; the colours of many different flowers, and the coat colours of animals; starchy or sugary endosperm in maize; shape of leaf in *Primula* and other plants. The question now arises, what happens if we follow two pairs of characters at once instead of only one? For example, we know that in wheat the cross rough × smooth chaff gives 3 rough : 1 smooth in F_2: and that beardless × bearded ears gives 3 beardless : 1 bearded. If we cross rough-beardless × smooth-bearded is the inheritance of one pair of characters bound up in any way with that of the other?

When the experiment is performed we find that they behave quite independently. In F_2, both among the rough plants and among the smooth plants there is a ratio of 3 beardless : 1 bearded. In other words the F_2 is made up as follows:

12 rough, of which there are	9 beardless	total	9 beardless-rough
	3 bearded		3 bearded-rough
4 smooth, of which there are	3 beardless		3 beardless-smooth
	1 bearded		1 bearded-smooth

To explain in greater detail how this result comes about, the cross rough-beardless, RRBB, × smooth-bearded, rrbb, will give the F_1 RrBb. This F_1 produces gametes in the proportion 1 R : 1 r, and 1 B : 1b ; or, if R and B are quite independent, 1 RB : 1 Rb : 1 rB : 1 rb. We therefore have four different classes of egg-cells which may each unite with any one of four different kinds of male gamete. The four egg-cells 1 RB + 1 rB + 1 Rb + 1 rb, uniting with the male gamete RB, produce the four F_2 seeds 1 RRBB + 1RrBB + 1 RRBb + 1 RrBb. Alternatively, they may unite with Rb, or with rB, or rb. To find all the F_2 plants produced by these various matings the simplest method is to use a checker-board. The four female gametes are written in a horizontal row repeated four times; to each

gamete in the first row is added the male gamete RB, to the second row Rb, to the third rB, and the fourth rb.

RB RB	Rb RB	rB RB	rb RB
RB Rb	Rb Rb	rB Rb	rb Rb
RB rB	Rb rB	rB rB	rb rB
RB rb	Rb rb	rB rb	rb rb

These 16 squares give the 16 seeds produced by the 16 possible matings between the different male and female gametes. If they are counted up it will be found that nine contain both R and B, and are therefore rough-beardless since R and B are dominant, three contain R but not B and are rough-bearded, three contain B but not R and are smooth-beardless, and one is without both R and B and is smooth-bearded. Altogether, therefore, we have the 9 : 3 : 3 : 1 ratio already given.

The important feature of this result is that from the two plants rough-beardless and smooth-bearded we can obtain, by crossing them together, the two new types, rough bearded and smooth-beardless. This is the basis of plant breeding by hybridization. Thus, English wheats have long been characterised by high yield, good standing, and rather low quality grain. To remedy this defect a search was made amongst foreign varieties of good quality; and though most of them did not retain their quality when grown in this country, eventually one—a Canadian variety known as Fife—was found which did do so. This variety, however, did not stand well and was not up to the existing English varieties in yield, so to remedy this it was crossed with several English forms; and from one of these crosses a new variety was obtained combining high quality grain with the good standing and high yield of the English varieties.

We have already seen that the usual object of breeding is to obtain the best pure line. In Mendelian language this means the production of a plant which is homozygous for all factors. The F_1 from a cross is usually, of course, heterozygous for very many factors—the number depending upon how different the two parents were. It follows that a large F_2 should be grown; not only to obtain the desired combination but to make it more likely that it can be found in a plant which is homozygous for as many other characters as possible. Otherwise selection will have to be continued over several generations to obtain purity; though in any case it is

not likely that a plant picked out in F_2 will be homozygous for all factors. In the example given above—rough-beardless × smooth-bearded—any desired combination, such as homozygous rough-bearded, only appears once in 16 times. And if the two parent forms differ by only five factors, not more than about one plant in every thousand would be homozygous for any five specified factors. This illustrates the fact that care should be taken to choose parents that are as alike as possible, so long as they have between them all the qualities that are wanted for the new variety. In practice, it is usual to pick out from the F_2 those plants that have, as far as can be judged, the characters wanted; and to raise a further generation, the F_3, from each one separately. Families that breed true for the wanted characters would probably be harvested, and the progenies of individual plants again grown separately so that choice can be made, as far as possible, of those that are homozygous for all factors. The actual number of generations over which selection is continued naturally varies with the circumstances of each individual case; but after it is over, testing for yield, and multiplication of the stock, would follow.

It will be clear that, unless selection has been continued for many generations, it is doubtful whether a pure line will actually be obtained. However carefully the parents are chosen they will probably differ by many factors; and completely homozygous segregates will be rare and difficult to recognize, unless selfing and selection are long continued. But the pure line principle, though an excellent means of improving existing varieties by selection, can be pushed too far when breeding by hybridization. Purity is a valuable feature, and is nearly always the ideal to be aimed at; while in barley it may be essential for quality. But in other crops, such as oats, it lacks this special value, and it may be better to use a new variety of outstanding merit at once, if it be reasonably pure, than to wait a further period of years for the best pure line to be selected from it. This final selection can be done after the new variety has been introduced.

In the simple case of inheritance described above, the characters depended for their development upon a single factor, T or t. Often, however, this is not the case; and a single character may depend upon two, three, or even more independent factors. Thus, in sweet peas red flower colour depends upon two separate factors, A and B. A plant lacking either A or B or both—one that is AAbb, aaBB or aabb, for example—has white flowers.

This was first discovered accidentally by crossing two white varieties, one of which happened to be AAbb and the other aaBB. The F_1, deriving Ab from one parent and aB from the other, had the formula AaBb; and since it possessed both A and B it had coloured flowers, instead of white like both its parents. Its gametes are 1 AB + 1 Ab + 1 aB + 1 ab, and the zygotes given by self-fertilization can be found from a checker board exactly as in the example of two factor inheritance, R and B, already given. If the

squares are counted up it will be found that nine of them contain both A and B, while the remaining seven lack either A or B or both. The F_2 therefore consists of plants with coloured and plants with white flowers in the proportion 9 : 7. Other instances may be still more complicated. Thus a third factor C changes red-flowered sweet peas to purple ; so that purple depends on three independent factors. There is no need to consider examples of this sort in any detail, since although they make for complexity they do not affect the general principles in any way. They merely illustrate the fact that a desirable character may depend on many factors instead of only one, so that it will be regained in F_2 in a much smaller proportion than 1 in 4 : *e.g.*, 1 in 16, 1 in 64, or even less frequently.

It has now been seen that in self-fertilized plants improvement may be brought about either by selection alone, to obtain the best pure line, or by creating new combinations, by crossing, and subsequent selection. In cross-fertilized plants, complications, which require the use of somewhat different methods, are introduced. Any individual plant is the product of a cross, and is almost certain to be heterozygous for many factors ; so that it would not breed true even if it were selfed, while probably its progeny will come from cross pollinations by many different plants. Consequently, uniformity cannot be found within the different varieties of such a crop, though an apparent similarity may be achieved. From a field of rye, containing plants with white and plants with coloured ears, it is not difficult to produce a variety with uniformly white ears, white being recessive to coloured, by selecting only white-eared plants and isolating them from possible cross pollination with coloured-eared plants. But the new white-eared variety will still be very mixed for characters such as yield and quality of grain. And although it may be easy to produce varieties of cross-fertilized crops which are uniform for the more obvious characters such as colour, which are usually simply inherited, these characters are not often economically important ; and to improve the more useful qualities, such as yield, or the sugar content of the cross-fertilized sugar beet, will be found more difficult.

In the sugar beet it is possible to measure the sugar content of single roots, though if this is done on a large scale it may be troublesome without a special organization. This gives a basis for selection. But sugar content probably depends on a number of factors, and many of the roots selected may be heterozygous for these factors, while others lack some of the factors altogether and owe their high content to fluctuation, that is to their being specially favourably situated with regard to soil or because they were not overshadowed by their neighbours. In neither case would the high sugar content of the roots be transmitted to their progeny : in the first case because the plants are heterozygotes, in the second because some of the necessary factors are not present at all. However, it is evident, that the first lot of roots would give better progeny than the second ; and even if the plants are not self-fertilized this would still

hold good to some extent, since in all cases the pollen applied will be more or less of a similar character, coming in fact, from good and bad plants indifferently.

These considerations show that if the roots with the highest sugar are selected and allowed to set seed under conditions of open pollination, and then the seeds of each root sown separately, some of the plots should have a higher sugar content than others, on the average. But within each plot roots would be found which were very good and others that were very bad. If the best roots are again selected from the best plots only, the seeds sown separately once more and this selection continued for several generations, an improved strain would probably be obtained in which comparatively few plants contained factors for low sugar content and many contained the factors for high sugar content. In fact, this method of individual selection, as it is called, has in the past improved the sugar beet considerably. From about 1850 to 1912 the average sugar content of the varieties was raised from 10 per cent. to 18.5 per cent. But it has not given us lines consisting entirely of roots homozygous for factors for high sugar content—as we might have expected if many factors are involved—so that the lines do not breed true even when they are isolated from other lines. This means that selection still has to be practised even to maintain the sugar content at its present level.

The method of individual selection we have just described was a great improvement on the previous method of mass selection. With the latter method the seeds of all plants with a high sugar content were sown together instead of separately. This meant that the progeny of roots which owed their good qualities to accident were mixed up with those of the roots that actually contained a greater number of the desired factors. Improvement was therefore much slower and more uncertain, though from about 1780 to 1850 the sugar content was probably raised from about six per cent. to ten per cent. by this method.

The possibility suggests itself that in crops of this nature self-fertilization might be enforced by isolating single plants completely, so that only their own pollen was available. Plants that were homozygous for desirable factors might then, perhaps, be picked out, and by multiplying these results might be obtained more rapidly. This has been tried with sugar beet, but so far with doubtful success ; partly because the plants set very little seed in such circumstances. But even in maize, which sets plenty of seed when selfed, serious difficulties arise because of a phenomenon that appears to be common to most, if not all, cross-fertilized plants. This is the fact that individuals homozygous for most of their factors are far less vigorous than the heterozygotes ; so that after a few generations of self-fertilization, when uniformity begins to appear, the plants obtained are comparatively stunted, yield poorly, and would be valueless for cultivation. If, however, different inbred lines are crossed, the F_1 plants are very vigorous ; and may even give a higher yield than the original variety.

Attempts have been made to take advantage of this hybrid vigour, as it is called. Suitable inbred maize lines are crossed on a large scale by growing the two lines side by side and knocking off all the male inflorescences in one line. A large amount of F_1 seed is produced in this way, but to obtain enough for commercial use it is now usual to raise a further generation by crossing two such series of F_1 plants together. The results are said to be promising, but so far the possibilities seem to be limited by the difficulty of getting enough seed under the careful supervision required for success.

It will be realized that, in general, breeding better varieties of cross-fertilized crops is difficult; and though in certain cases improvements have been brought about it may be doubted whether any really satisfactory method has yet been found. Moreover, further practical difficulties arise in trying to keep pure those varieties that already exist. Isolation is necessary, for example, to maintain the varieties of mangold which differ from one another in the colour or shape of their roots. And since mangold pollen is easily carried several miles by the wind this means that when seed is being produced steps have to be taken to see that no other stock is being grown at the same time anywhere within a considerable radius. In some parts of the world Government legislation is enforced to ensure the purity of stocks of cotton seed. In this crop uniformity is important; and, though it is chiefly self-fertilized, crossing is frequent enough to cause rapid deterioration in the quality of the stocks, so only one variety is allowed to be grown in any one district.

Further problems that arise in plant breeding practice can only be appreciated with a knowledge of the mechanism of cell division. Sexual reproduction consists in the union of two cells to form a single cell, which in its turn gives rise to the adult organism by a series of divisions. This organism, again, produces germ cells—egg cells and male gametes—by divisions of a special type; and, from the union of these, further individuals are produced. This suggests that heredity is closely connected with the mechanism of cell division, and in fact the science of "cytology"—the study of cells, and particularly the way in which they divide—has made clear many difficult problems in heredity.

The plant cell consists of a nucleus, usually spherical in shape, imbedded in the cytoplasm, which in its turn is usually surrounded by a solid cell wall. Nucleus and cytoplasm are the only essential constituents of the cell and are both of semi-fluid semi-jelly-like consistency; but the structure may be complicated by the presence in the cytoplasm of watery vacuoles and organized bodies such as chloroplasts. The division of a cell, or of the nucleus at least, is a far from simple process. The nucleus first condenses into a number of rod-shaped bodies, the chromosomes (Fig. 72A), which soon arrange themselves in a single plane across the centre of the cell, fig. 2. In this position, when seen from above or below, they can be counted

without great difficulty and the same number is found in all the cells of any individual plant or animal body ; and, with a few exceptions, in all the individuals of a species. They can usually be seen to be split longitudinally by the time this stage is reached, and shortly afterwards the split halves separate from one another, travel to opposite poles of the cell, fig. 3, and form two daughter nuclei, fig. 4, each containing the same number of chromosomes as the original nucleus. The formation of a wall across the middle of the cell, and the apparent dissolving of the chromosomes to give the semi-fluid nucleus again, complete the division. The whole of the process can be followed in living cells, but since the chromosomes are transparent they are difficult to observe accurately so the method usually adopted is to treat the material to be studied with a solution which kills the cells and preserves the contents as far as possible in an unchanged condition. The cell contents are then stained so that they can be studied in detail.

Although the chromosomes cannot be seen in the resting nucleus, the same number reappears at every division. Very often, too, one or more of them can be recognized by their shape, or some peculiarity in their structure, which enables them to be picked out with certainty

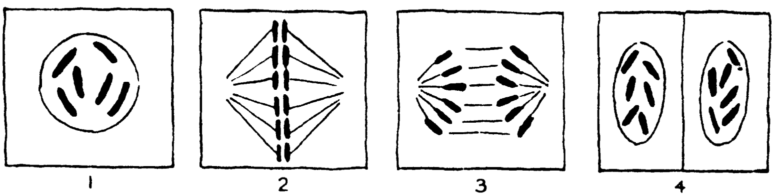


FIG. 72A.—NOS. 1—4 : SOMATIC CELL DIVISION WITH SIX CHROMOSOMES.

at each reappearance. For reasons of this sort it appears that although they disappear from view after each division, and no doubt undergo changes of some sort, they never lose their individuality. Moreover, this elaborate mechanism of division, which seems to ensure that every daughter nucleus will receive an identical share of chromosome material, is very striking. We already know that all the cells of the plant body are probably alike in their hereditary qualities, since a whole plant may be regenerated from a cutting, from a fragment of root, or even in some cases from a few cells of the leaf. It is likely that the reason for this identity is the equal division of the chromosomes at cell division, and that the chromosomes are in fact responsible for carrying the hereditary properties of the organism. These conclusions have been amply confirmed by other evidence.

There is one division which is of a different type from the somatic division we have just described. This is the division by which the germ cells—egg cells and male gametes—are produced. It is known as the "reduction division," because it brings about a reduction in the chromosome number to one half the previous number ; so that the germ cells contain half the number of chromosomes that

the somatic cells contain. When two germ cells unite at fertilization the full chromosome number is restored; and by a series of ordinary somatic divisions we obtain a new individual, every cell of which contains the same number of chromosomes as the parent organism.

At the beginning of the reduction divisions, when the chromosomes first appear, they are found to be associated in pairs (Fig. 73); and in species in which the different chromosomes can be recognized, *e.g.*, because they have different lengths, the two members of each pair are found to be alike. These paired chromosomes, or bivalents as they are called, arrange themselves across the centre of the cell, fig. 6, and the two members of each pair separate and pass to opposite poles, fig. 7. Here, two daughter nuclei containing the reduced number of chromosomes, half the original number, are formed, fig. 8. These two nuclei immediately undergo a second division, figs. 9 and 10, exactly like an ordinary somatic division except that only half as many chromosomes are engaged; so that

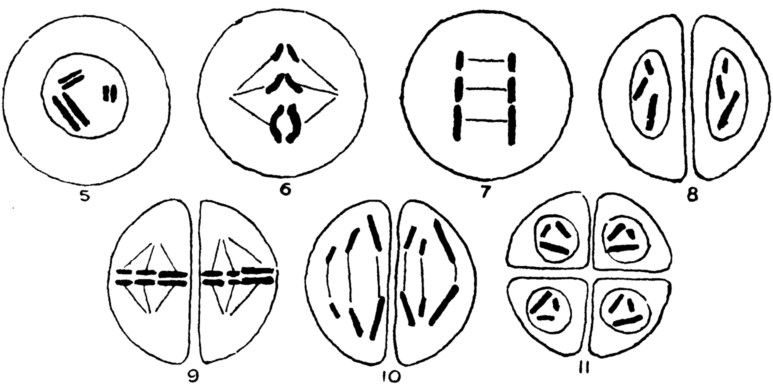


FIG. 73.—NOS 5—11: REDUCTION DIVISIONS; SIX CHROMOSOMES FORMING THREE BIVALENTS.

finally we have four cells each with the reduced number of chromosomes, fig. 11. From each of these four cells a germ cell is formed by a series of ordinary somatic divisions.

When fertilization occurs in a plant with three chromosomes in its germ cells, an egg cell with three chromosomes, which we will call A, B and C, unites with a male gamete carrying three similar chromosomes, a, b and c. The new individual has six chromosomes, AaBbCc. At the reduction division these do not, as we have seen, pair in a haphazard manner; instead, the two members of a pair are always similar. This means that A pairs with a, B with b, and C with c; and when the members of a pair separate, A goes to one pole and a to the other, so that any germ cell may contain either A or a but not both.

This is exactly the mechanism of Mendelian heredity, in which, it will be recalled, the F_1 hybrid Aa produces germ cells carrying either A or a, and these mating at random give 1 AA + 2 Aa + 1 aa.

Clearly, too, AA and aa will breed true; and Aa split up again. This obvious parallellism between the segregation of the chromosomes and the segregation of the Mendelian factors confirms the conclusion that the chromosomes carry the hereditary material of the organism. The conclusion has been abundantly confirmed by cases in which chromosome segregation and factor segregation are both abnormal and show the same irregularity.

When the chromosomes segregate during the reduction divisions, the pairs behave independently of one another; and it is because of this that Mendelian factors segregate independently: the cross rough-beardless × smooth-bearded giving, in F_2, the new forms rough-bearded and smooth-beardless as well as the original combinations. When A goes to one pole and chromosome a to the other, it will sometimes happen that B goes to the same pole as A and sometimes that b does; and the gamete AB will be obtained as often as the gamete Ab. This means that so long as two factors A and B are carried by different chromosomes an F_1 AaBb will produce the gametes 1 AA + 1 Ab + 1 aB + 1 ab just as Mendelian theory demands. But this will only occur so long as A and B are carried by different chromosomes. Experiment shows that when they are carried by the same chromosome they are no longer inherited quite independently.

This complication does not involve a fundamental change in plant-breeding methods, but may give difficulty in particular cases. Thus the ordinary cultivated oat bears two or three grains in each spikelet; and the grains themselves are tightly invested by the paleæ or husk. A Chinese oat has as many as eight or ten grains to each spikelet; but these grains are not held by the paleæ and easily fall out. Crosses have been made to try to combine the high number of grains per spikelet with the non-shedding character of the European oats; but so far without success, since the characters many grains per spikelet and easily shed cannot be separated—they are completely linked. This complete linkage is comparatively rare, however. It is commoner for two characters, though associated, to separate more or less frequently so that the new combination can be obtained. The only difficulty is that this separation may occur in rather a small proportion of cases, so that to obtain what is wanted large F_2 populations must be grown. In certain wheat crosses made in Canada and the United States it has been found that rust resistance is linked with a type of grain unsuitable for bread-making; but the linkage is not complete so that plants combining resistance with high-quality grain have been obtained eventually.

Now that it is known that the segregation of Mendelian factors is a consequence of the segregation of the chromosomes at the reduction divisions, it has been possible to understand many cases of irregular inheritance that were formerly inexplicable. A simple example is the inheritance of sex and of sex-linked characters in animals. In most animals the female has two sex chromosomes XX,

often recognizably different from the others ; while the male has one chromosome, like the X in the female, and one Y, which may be missing altogether or recognizably different from the X. The females, of course, transmit X to all the egg-cells ; but the males transmit either X or Y to the sperm in the proportion 1 X : 1 Y. Mating between them gives 1 XX : 1 XY, that is to say, females and males in equal numbers.

female XX → egg-cells X

male XY → sperm 1 X : 1 Y

1 XX : 1 XY
female male

Characters controlled by factors in the sex chromosomes show a special type of inheritance, known as "sex-linked" inheritance, which may be illustrated by a case—one of the first to be worked out—in the fruit fly *Drosophila melanogaster*. The character concerned is white eyes, as opposed to the normal red eyes. It is a recessive character, carried by a sex chromosome, which can be denoted **X**. **X**Y flies are white-eyed males, since Y, which rarely carries any factors at all, does not carry the dominant allelomorph for red eyes. When white-eyed males, **X**Y, which will transmit **X** or Y to their sperm, are mated to normal females XX, transmitting X to all the egg-cells, we obtain normal males XY, and red-eyed females X**X** which carry the factor for white eyes.

female XX → egg-cells X

male **X**Y → sperm 1 **X** : 1 Y

1 X**X** : 1 XY
heterozygous females red-eyed males

If these X**X** females are mated in their turn to red-eyed males XY, we shall obtain white-eyed males **X**Y, red-eyed males XY, and red-eyed females X**X** and XX, of which half carry the character.

female X**X** → egg-cells 1 X : 1 **X**

male XY → sperm 1 X : 1 Y

1 **X**Y : 1 XY : 1 X**X** : 1 **XX**

This means that the original white-eyed male transmitted the character to none of his sons but through all his daughters, who do not show it, to half his grandsons. Other matings give similar results, which are easily worked out.

Sex-linked inheritance has an important bearing on poultry husbandry, since by suitable matings it is possible to tell the sex of a chick as soon as it hatches. In birds, unlike most animals, the male has two similar chromosomes ZZ, and the female two dissimilar ones ZW. The factor B for one of the types of barred plumage is sex-linked, so that males carrying the factor may be denoted $Z_B Z_B$ The females are $Z_B W$, and it so happens that the barring is different because the factor B is present only once instead of twice, as it is in the male.

Important examples of irregular inheritance have been given by hybrids between distinct species. Although the chromosome number of most species is constant, nearly related species often have different numbers ; in both wheat and oats, species with 14, 28 or 42 chromosomes may be found. Nearly all our British wheats belong to the species *Triticum vulgare* and have 42 chromosomes ; but one of them, the variety Rivet, belongs to a different species, *T. turgidum*, with 28 chromosomes. The latter stands well and yields heavily on suitable soils, but has a grain of very poor quality ; and attempts to transfer its good features to other wheats have met with great difficulties. In the light of the fact that it has a different chromosome number from the other forms this is easily understood. The F_1 contains 35 chromosomes, of which 14 were derived from one parent and 21 from the other ; and, in consequence, chromosome behaviour during the reduction divisions is very irregular. This in its turn makes the F_1 partially sterile and the breeding behaviour very complex. This has only been understood by working out the behaviour of the chromosomes at the reduction divisions.

Crops like the sugar cane and most fruits, which are reproduced vegetatively, are in one way simpler to breed than those propagated by seed since the problem of ensuring fixity does not arise. The members of a variety are simply parts of a single individual, and are all identical. It is not surprising to find that such varieties are usually complicated heterozygotes, giving a very mixed progeny if they are selfed or crossed with other varieties. In many fruits, indeed, the chromosomes behave irregularly during the reduction divisions and a certain amount of sterility results, many of the egg-cells failing to get fertilized, so that the young ovaries drop off soon after the flowers have faded. In the apple this need not interfere with the yield, because a good yield is obtained if only a small proportion of the flowers set fruit ; but in the cherry, which needs as many fruits as possible to give a good crop, varieties with irregular chromosome behaviour could not usually be grown for their fruit.

Breeding crops of this kind involves raising large numbers of seedlings ; either by selfing, or by crossing different varieties, or even different species, which need not necessarily have the same

chromosome number. The difficulties lie in the number of seedlings that must be raised, since the great majority will be worthless; in the fact that inheritance is likely to be very complicated; and in cases such as most fruits in the fact that a long period elapses before maturity is reached.

At the present time the greatest improvements in crop varieties are likely to come in the newer countries of the world. In the older European countries, which have long practised an intensive system of agriculture, the varieties of crops now grown are usually of a high standard; and further improvement is becoming more difficult, except where new varieties are required to meet changed conditions: new cereals that will stand up to large doses of artificial manure, fruit and vegetable varieties suitable for canning, and so on. With the rapid advance of the science of genetics, however, it is likely that new methods, giving scope for still further improvement, will be devised

For further information on this subject the following books are suggested:—

Punnet, R. C. *Mendelism.* Macmillan, London.
Babcock, E. B. and Clausen, R. E. *Genetics in Relation to Agriculture.* McGraw Hill Book Co., New York.
Punnett, R. C. *Heredity in Poultry.* Macmillan, London.
Wriedt, C. *Heredity in Livestock.* Macmillan, London.
Crew, F. A. E. *Animal Genetics.* Oliver and Boyd.

CHAPTER XVIII.

STRUCTURE AND FUNCTIONS OF THE ANIMAL BODY.

THE body of a higher animal such as a man, a horse, a dog, or a fowl is, in common with all except the simplest forms of life, built up of a number of structural units or cells, microscopic in size and packed together in various ways. Each cell consists of a minute mass of protoplasm or living substance containing within it a certain specialized portion known as the nucleus. In individual development the cells are all derived from one, the fertilized egg cell, which is formed by the union of a male cell with a female cell derived respectively from the essential reproductive organs of the male and female parents. This is true not only of man and the animals of the farm but of the great majority of animal organisms, besides a large number of plants, as already described. The fertilized egg cell or ovum in initial development undergoes division into two; the two halves then divide and the process of multiplication is repeated not only throughout the period of growth but to a less extent during the whole of adult life. New cells formed in this way replace old ones which die and disintegrate. In this process the nuclei of the cells also divide so that each new cell contains a nucleus like the mother cell. During the progress of development the cells become gradually specialized to form the different tissues—bone, cartilage or gristle, muscle, nerve, gland, etc.

—which have particular functions, each kind serving a special purpose and contributing to the well-being of the animal as a whole. Thus, the outer layer of cells forming the skin becomes adapted for protection and for receiving impressions produced by changes in the surroundings ; the inner layer lining the gut becomes adapted for the digestion and assimilation of food ; while between these are developed the skeleton and general framework of the body, and all the other tissues which unite in performing the vital functions. In the adult animal there are millions of cells of different shapes and sizes but each consisting of a nucleus and protoplasm external to the nucleus, and these cells, together with a varying amount of intercellular substance, which is derived from the cells, go to compose the body.

The study of the structure of animals, whether it be the gross structure which is visible to the naked eye or the minute structure of the tissues and cells which can only be investigated in detached portions under the microscope, is included under the term Anatomy. The study of the uses or functions of the various organs and parts is known as Physiology. These two subjects should always be considered in relation to one another, since it is impossible to understand the functions of the parts of an organism without some knowledge of their composition and structural relations, and conversely, a true comprehension of the anatomy of an organ can only be gained by a consideration of the part which that organ plays in the general economy of the individual.

Many of the functions of the body are essentially similar throughout the whole animal kingdom, and among Vertebrates or backboned animals there is a still closer resemblance. Thus, the processes of digestion in a frog, a bird, a rabbit, a horse and a man are broadly speaking similar, though there are of course marked differences which are generally greater the less closely related the animals are. So also the general laws governing muscular movement, the circulation of the blood, or the processes of reproduction are identical in every case. Thus, by investigating these processes in any one species of animal, we can learn a good deal about the functional activities of another species and more especially if they belong to the same group.

Horses, cattle, sheep and pigs which constitute the principle livestock of the farm, all belong to the class Mammalia, which is the highest of the five classes which together compose the Vertebrata. The other classes in descending order are birds, reptiles, amphibians (frogs, newts, etc.) and fishes. The Mammalia are warm blooded, hair-clad animals, which suckle their young, and in which with only two exceptions, the young undergo an embryonic development within the body of the mother.

In what immediately follows the horse is taken as the type for study, special reference being made to the other farm animals when they differ markedly from it.

Regions of the Body.—A broad distinction may be drawn between body and limbs. The former is divided into head, neck, trunk, and

tail, while the fore and hind limbs are attached respectively to the front and back of the trunk. The upper surface of the body is conveniently termed "dorsal" and the under surface "ventral," while "anterior" and "posterior" technically replace the ordinary words fore and hind.

In the trunk of a mammal there are two regions. The anterior one is the "thorax" or chest, and the posterior one the "abdomen" or belly—spoken of as the "barrel" in a horse. The thorax is completely separated from the abdomen behind by a transverse partition called the "diaphragm," and, though certain tubes—the gullet and some of the blood-vessels—pierce the diaphragm, their passage does not establish any communication between the cavities of the thorax and abdomen.

When the thorax is opened, it is seen to contain the heart, with the lungs on either side of it. The heart is the organ whereby the circulation of the blood is effected. The lungs, called "lights" by the butcher, are concerned in the work of respiration or breathing.

When the abdomen is opened, the chief organs seen at first are the stomach and intestines. By turning the latter on one side, it is possible to bring into view the liver, the kidneys, and certain other organs.

The Skeleton.—If a horse were divested of all its soft parts, there would be left a bare framework of bone, gristle, and fibrous tissue, called the "skeleton," which supports or carries all other portions of the body.

The skeleton (Fig. 74) is made up of an "axial" part and an "appendicular" part, the former including "skull," "backbone," "ribs," "breast-bone" (sternum), while the latter comprises the skeleton of the appendages or limbs. The fore limbs join, or "articulate," to the axis by means of a "shoulder-girdle," the hind limbs by means of a "hip-girdle."

The backbone is often termed the "vertebral column," because it is really a chain of bones, each of which is called a "vertebra." Each vertebra is a ring, of which the dorsal part is the "arch" and the thickened ventral part the "body." When the vertebræ are placed end to end they form a tube, which, as it contains the great nervous axis—the spinal cord—is called the "neural canal." In the living animal, the bodies of the vertebræ are not actually in contact, there being between each pair an elastic pad or cushion, consisting of "gristle" or "cartilage." Hence, the backbone as a whole possesses some degree of pliancy, as is seen when a cat arches its back or a man stoops to the ground.

The backbone comprises several regions. In the horse, as in nearly all mammals, there are seven "cervical" or neck vertebræ. These are succeeded by eighteen "thoracic" or chest vertebræ, which support the ribs, and are above the chest or thorax. Next come six "lumbar" or loin vertebræ; then five "sacral" vertebræ, fused together into one piece, the "sacrum"; and finally about seventeen "caudal" or tail vertebræ within the tail.

The neck vertebræ of the horse are almost cubical. Above them pass the "ligaments" of the neck, strong fibrous bands which hold up the head. The first neck vertebra, or "atlas," is an oval ring, on the anterior side of which are two deep cups that fit on to two corresponding knobs ("occipital condyles") on the back of the skull, constituting a hinge-joint, that renders nodding movements possible. The second neck vertebra, or "axis," is also exceptional in character. A blunt peg ("odontoid process") projects from the front of its body through the cavity of the atlas, and is attached to the back of the skull. The head and atlas can be moved from side to side round this peg, which

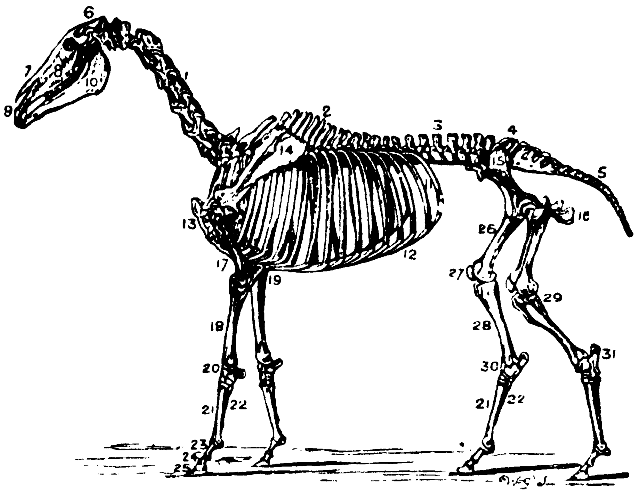


FIG. 74.—SKELETON OF HORSE.

1, cervical vertebræ.
2, thoracic vertebræ.
3, lumbar vertebræ.
4, sacral vertebræ.
5, caudal vertebræ.
6, parietal bone.
7, nasal bone.
8, maxillary bone.
9, premaxillary bone.
10, mandible.
11, ribs.
12, costal cartilages.
13, sternum.
14, scapula.
15, ilium.
16, ischium.
17, humerus.
18, radius.
19, olecranon process of ulna.
20, carpus (knee).
21, cannon bone.
22, splint bone.
23, pastern.
24, coronet.
25, coffin bone.
26, femur.
27, patella (stifle joint).
28, tibia.
29 fibula.
30, tarsus (hock).
31, calcaneum (heel bone).

serves as a pivot. The arrangement is, in fact, a pivot joint. The chest vertebræ possess bony spines which extend upwards, the longest ones being at about the middle, and each such vertebra supports a pair of ribs. The loin vertebræ have large flat lateral projections, which are well seen in a "saddle" of mutton. In the adult horse, the five sacral vertebræ are fused together into one bony

piece called the sacrum, which supports the hip-girdles. In the sacral and in the succeeding caudal vertebræ there is no continuation of the neural canal. The caudal vertebræ are, indeed, reduced to solid bony cylinders.

At its anterior end, the central bony axis is greatly modified, and takes the form of the skull. The tube or canal, which extends along the backbone, here expands into a large cavity, surrounded by bone; this is the "cranial" part of the skull, constituting the "brain-case" or "cranium," which lodges the brain. A still larger portion is seen in front and below, and comprises the "facial" part of the skull. The side-walls and roof of the cranium are made up of flat thin bones, chiefly the "parietal" bones at the sides, and the "frontal" bones in front, extending above and between the eyes. Much of the front part of the face is supported by the "nasal" bones, which are long flat triangular bones roofing in the cavities of the nose. On either side of the nasal bones are the "maxillary" or upper jaw bones, which carry the upper grinding teeth ("premolars and molars"). Extending forward, and carrying the upper cutting teeth ("incisors") are the two "premaxillary" bones. Two large flat bones, right and left, make up the powerful lower jaw, or "mandible," in which the lower teeth are embedded. They are fused together in front, and diverge from each other backward, at length articulating by a convex projection ("condyle") on each side with the upper part of the skull.

Of the eighteen pairs of ribs, the flattest are in front, and those most arched are behind. Each rib is made up of a bony part above and of a gristly or cartilaginous part below, this gristly part being called the "costal cartilage." In the first eight pairs of ribs, each costal cartilage communicates separately and independently with the sternum, or breast-bone, below; these are called "true-ribs." In the remaining ten pairs of ribs the cartilages run together, as it were, and only in this way become attached to the sternum; these are called "false ribs."

The sternum, or breast-bone, of the horse is narrow and keel-like. The sternum of the ox, on the other hand, is broad and flat, and imparts to that animal the broad-chested appearance seen above the dew-lap.

Each "shoulder-girdle" in the horse is very simple, consisting merely of a "shoulder-blade," or "scapula." The fore-leg of the horse is restricted in its movement, being capable only of a motion backwards and forwards. It cannot move sideways, so that there is no necessity for a "clavicle" or "collar-bone," such as exists in man, but is absent in the horse. The scapula on each side is slender, and has at its lower extremity a shallow cup ("glenoid cavity"), in which the head of the upper-arm bone ("humerus") works. A bony ridge extends along the outer face of the scapula. The ridge is thickened and turned backward above the middle, so that it is always easy to determine whether a separate shoulder-blade belongs to the right side or the left.

Each "hip-girdle" in the horse is less simple and more complete. It consists of an "innominate bone," made up of three parts, which are distinct in the young animal, but fuse into one piece as age advances. The large triangular bone which extends forward, and the rough extremity of which projects so prominently in a lean animal, is the "ilium," "pin-bone," or "haunch-bone." The bone extending backward to the side of the tail is the "ischium." The flat bone beneath, joining with its fellow in the middle line, is the "pubis," the place of union of the two pubic bones being called the "symphysis pubis." The three elements of the innominate bone—ilium, ischium, and pubis—all meet together in a deep cup, the "acetabulum," into which the head of the thigh-bone ("femur") fits. The two ischia do not meet above, although they incline towards each other, the sloping surfaces resting one on each side of the sacrum. Hence, looking at them below from the front, the hip-girdles, with the sacrum form a complete bony ring or basin (the "pelvis"), which is much more capacious in the female than in the male. The long axes of the hip, on which depends the relative size of the "quarters" in a horse, form an acute angle with the vertebral column.

The limb-bones of the horse can be best understood by comparing them with the corresponding bones in man. Place the hand on the bone which extends from the shoulder to the elbow; this is the "humerus" or upper-arm bone. The humerus of the horse can easily be felt, but it is hidden beneath the skin; nevertheless, when the horse walks, the movements of the humerus are at once noticeable.

Lay your left forearm flat on the table, with the palm of the hand facing upwards. This is the supine position; and the thumb is on the outer side. Feel the two parallel bones which extend from the elbow to the wrist—the one on the thumb side is the "radius"; the other one is the "ulna." These bones are separate throughout their entire length, so that the radius, bearing the wrist and hand, may be made to rotate round the ulna. Without moving the elbow, turn the left hand completely over. Its palm will now face downwards, and the thumb, as well as the lower end of the radius, will have described half a circle, so that the radius and ulna, instead of being parallel, will now be crossed. This is the prone position, and the thumb is now on the inner side. At the elbow joint, the ulna can be felt to project backwards, forming the "olecranon process" (the so-called "funny-bone") of the ulna.

The fore-limb of the horse contains the same two bones—ulna and radius—as the forearm of man. But, in the horse, the ulna, though it has a prominent olecranon process, dies away, and terminates in a button-shaped end rather more than half-way down the radius. The two bones are immovably united together, and the forearm is permanently fixed in the prone position.

In the horse, the region popularly termed "the knee" corresponds with the wrist of man. The anatomical name is the "carpus," and it consists of an upper and a lower row of "carpal bones," freely

inter-locked so as to prevent lateral twisting such as occurs so readily and usefully in man.

There are three bones in the upper row and three in the lower row. An additional bone (the "pisiform") projects at the back of the carpus. It is an example of the class of "sesamoid bones," which are developed within tendons, the strong fibrous cords by which muscles are fixed to bones. Each bone has smooth joint surfaces, and is provided with delicate membranes which secrete lubricating "joint oil," or "synovial fluid." The whole arrangement is such as to constitute entire security against concussion. At the same time it permits the animal to use the fore-limbs freely without risk of fracture, even when drawing heavy loads, or carrying considerable weight in the saddle at great speed.

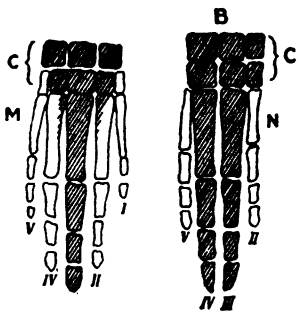


FIG. 75.—DIAGRAMMATIC REPRESENTATION OF THE FORE-FOOT OF—
A, an odd-toed or perissodactyle animal.
B, an even-toed or artiodactyle animal.
C, carpus or wrist ("knee").
M, metacarpus.
I—V, digits.
The shaded parts indicate the bones that are *present* (A) in the horse, (B) in the ox and sheep.

FIG. 76.—SIDE VIEW OF BONES BELOW KNEE (CARPUS) OF HORSE.
A, cannon bone.
B, B, sesamoids.
C, pastern.
D, coronet.
E, coffin bone.
G, navicular (a sesamoid bone).

The "foot" of the horse is merely a remnant of the foot as it existed in the extinct ancestors of the animal. Its bony framework will be best understood by comparison with the hand of man. Lay the left hand on the table, and notice the five digits—I, thumb; II, forefinger; III, middle finger; IV, ring finger; V, little finger. Feel the back of the palm, and notice that at the base of each digit there is a long bone extending between the digit and the carpus or wrist. These are the "metacarpals" or "palm-bones," and they may be referred to as metacarpal 1 (from wrist to thumb), metacarpal 2 (from wrist to forefinger), etc. The metacarpal bones are collectively termed the "metacarpus."

In the case of the horse (Fig. 75), the only one of these bones which is well developed is metacarpal 3, corresponding with the bone extending from the wrist to the base of the middle finger. It is this bone (metacarpal 3) which forms the hard solid " cannon bone," or " shank bone " in the fore-foot (or hand) of the horse. This cannon bone is flanked by two very slender bones, which can be felt, one on each side. These are the " splint bones " ; that on the inner side is metacarpal 2, and that on the outer side is metacarpal 4. These splint bones do not extend the whole length of the cannon bone. Metacarpal 1 and metacarpal 5 have entirely disappeared in the horse; the digits, I, II, IV, and V are likewise absent. But, as if to compensate for this suppression of four of the digits, the remaining digit (III) is enormously developed. The arrangement, in fact, has gradually been evolved as an adaptation to rapid movement on a firm surface, where numerous small bones would be disadvantageous. In correlation with this reduction the carpus has been raised high above the ground and the two rows of its component bones have become interlocked, as already described, in such a way as to admit of a forward and backward motion and without allowing any rotation or lateral motion such as is shown by the hand of a man. The whole arrangement is thus adapted for rapid movement over the ground. As will be shown, later, the hind limbs in the horse have undergone a parallel modification during the progress of evolutionary development. The original stock from which horses have been derived consisted of small swamp-dwelling creatures, possessed of four or five digits to each foot.

Double up the middle finger of the left hand, and notice the three joints—a basal joint next to metacarpal 3, a middle joint, and a terminal joint bearing the nail. The bones in these three joints are well seen in the single digit (Fig. 76) of the horse. The uppermost one is called the " pastern," the middle one is the " coronet " (so called because the " crown " of the hoof is around it), and the terminal one (buried in the hoof) is the " coffin " bone. The hoof corresponds to the nail of a man's finger, but instead of being developed only on the back surface, it extends also round the front and sides. Behind the articulation of the coronet with the coffin bone, a " floating " bone extends across from side to side. Veterinarians call this bone the " navicular," and it occupies the region of what is known as navicular disease.

The bones of the human leg have their counterparts in the hind-leg of the horse. The " femur," or thigh-bone, extending from the hip to the knee, is hidden by the skin, but its movements can easily be seen as the horse moves. The femur has an almost spherical head, which fits into the acetabulum, thus forming a ball-and-socket joint. About one-third of the way down, on the outer side of the femur, is a roughened projection, in the form of a compressed ridge curving forwards, called the " third trochanter," affording a surface of attachment for some of the powerful muscles that move the hind limbs. In cattle, sheep, and pigs, the femur has no third trochanter.

In the human leg there are two long bones extending from the knee to the ankle joint. Of these, the "tibia," or shin-bone, is the stout strong bone on the inner side, and the "fibula" is the slender bone on the outer side. Both of these exist in the horse, but the fibula is extremely slender. In front of the human knee may be felt a "floating" or sesamoid bone, the "patella," or knee-cap, which also exists in the horse, at the region termed the "stifle joint." The patella is attached by three strong ligaments to the tibia.

The bones in the human ankle are represented by the hock, in the horse. The anatomical name for this region is the "tarsus," and the bones composing it are called "tarsal bones." In man, however, the tarsal bones, as well as the metatarsals and the digits of the foot, are laid flat on the ground, while in the horse they approach the perpendicular position. Suppose the "near" hind-leg of a horse to be

CALCANEUM

ASTRAGALUS

NAVICULAR

CUBOID

EXT. C.

INT. CUNEIFORM

FIG. 77.—DIAGRAMMATIC VIEW SHOWING THE POSITIONS OF THE BONES IN THE TARSUS, OR "HOCK" OF THE HORSE.

looked at from the front, then Fig. 77 shows the names and positions of the bones that make up the hock.

On the outside of the hock the bones are seen to be two deep, the "calcaneum," "os calcis," or heel-bone, projecting upwards and backwards, and below it being the "cuboid." On the inner side of the hock the bones are three deep, the uppermost bone being the "astragàlus," which has a beautiful pulley-like surface for articulation with the lower end of the shin bone or tibia.

The bones of the horse's hind-foot are similar in name and position to those of the fore-foot, and may be compared with those of the human foot in the same way as the horse's fore-foot was compared with the human hand. In man, the instep and toes of the foot correspond with the palm and fingers of the hand. The bones of the instep, being beyond the tarsals, are, however, called "metatarsals," so that the cannon bone of the horse's hind-foot corresponds with metatarsal 3, the inner splint-bone is metatarsal 2, and the outer splint-bone is metatarsal 4. The metatarsal bones are collectively termed the "metatarsus."

It is now possible to show the correspondence between the fore-limb and the hind-limb of the horse :—

Fore Limb.	*Hind Limb.*
Shoulder-girdle, or pectoral arch (scapula)	Hip-girdle or pelvic arch (innominate bone).
Humerus	Femur.
Radius	Tibia
Ulna	Fibula
Carpals (" knee ")	Tarsals (" hock ").
Metacarpals (cannon bone and splints)	Metatarsals (cannon bone and splints).
Digital region (" foot ") ... ... (Pastern, coronet, and coffin bones)	Digital region (" foot "). (Pastern, coronet, and coffin bones).

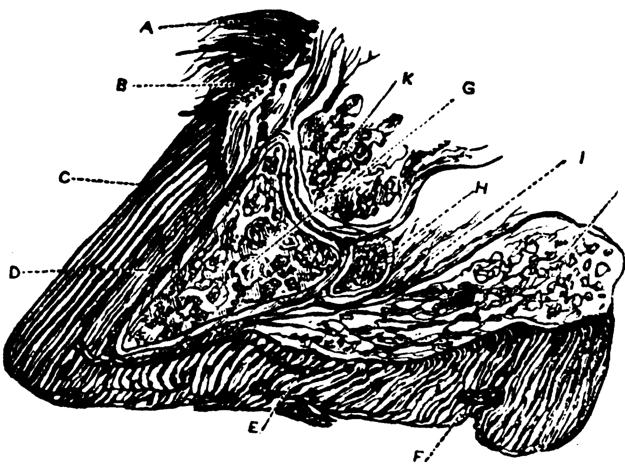


FIG. 78.—VERTICAL SECTION THROUGH MIDDLE OF HORSE'S HOOF.

A, skin of coronet.
B, fibres of coronary frog band.
C, fibres of wall.
D, horny lamina.
E, fibres of sole.
F, fibres of frog.
G, section of coffin bone.
H, section of navicular (a moid bone).
I, section of flexor tendon.
K, section of coronet bone.
L, section of fatty frog.

At the back of the articulation of the cannon bone with the pastern, there are, in each limb of the horse, a couple of " floating " sesamoid bones (Fig. 76 B, B). Externally they are covered with a horny growth, the " ergot," overlaid with a long tuft of hair, the " fetlock " (*i.e.*, " footlock "). Fetlocks are peculiar to the horse, and vary in length and coarseness with the breed.

The Hoof of the Horse.—The coffin bone, the navicular, and the lower end of the coronet, form " the articulation of the foot " (Fig. 78). Four ligaments bind this articulation together. In addition, the " extensor tendon " passes down the front, and the " flexor tendon " behind. Outside these structures are two fibro-cartilages, one on each side, united behind and below by the " plantar cushion." Outside, again, and fitting on the foregoing like a sock on a foot, is the

"keratogenous" (*i.e.*, horn-producing) membrane, which secretes externally the epidermal material known as the horn, of which the hoof is composed. The entire region is richly supplied with blood-vessels and nerves. The hoof is seen to become continuous with the ordinary skin at a circular line extending round the middle of the coronet; below, both in front and at the sides, is a semi-circular protuberance, the "coronary cushion." That part of the keratogenous membrane which is spread over the anterior face of the coffin bone is called the laminal or leafy tissue, because of the laminæ or parallel leaves seen on its surface; inflammation of this structure is called "laminitis."

The hoof fits closely on the keratogenous membrane, of which, indeed, it is the product. Its general shape is that of a cylinder cut across obliquely. Prolonged maceration causes it to separate into three parts—the wall, the sole, and the frog.

The "wall," or "crust," is that part which remains visible when the hoof rests upon the ground. The middle anterior part is the "toe" (outside and inside); the lateral regions are the "quarters"; the angles of inflection at its hinder extremities are the "heels"; from thence, passing along the inner border of the sole, are the "bars," which form outwardly the external faces of the "frog." The "sole" has a large external curved border, and a much shorter internal border taking the form of a deep V-shaped notch, widest behind. This latter corresponds with the bars, at the meeting of which the point of the frog is fixed. The "frog" is a pyramidal mass of horn lodged between the two re-entering portions of the wall. A "median lacuna," divides the inferior face of the frog into two divergent branches, the round, flexible, elastic, free ends of which are the "glomes." The flexibility of the hoof is promoted by a fluid secreted by the keratogenous membrane. At the junction of the wall and sole is the "white line"; it is soft and flexible, and so prevents the breaking of the sole from the wall. The growth of the wall may continue indefinitely, but the sole and frog, after attaining a certain thickness, begin to peel off, unless otherwise kept down. The wall grows from its superior to its inferior border, like the human nail. The sole and frog grow from their deep-seated to their external face.

The skeleton of the ox (Fig. 79) differs from that of the horse, in that the ribs are longer, wider, and flatter (notice a piece of "ribs of beef" in a butcher's shop). The sternum is flat, not keel-like. The scapula is much broader at the top. The premaxillary bones do not carry teeth, so that the ox has no incisors or front teeth in its upper jaw, their place being taken by a hard pad, against which the incisors and canines of the lower jaw bite. In the skull the frontal bone is greatly developed; it is this bone that is pierced between the eyes by the pole-axe when a beast is slaughtered. The upper part of the frontal bone, in the region of the poll, is so thick that it is occupied by sinuses, or cavities, and it forms laterally the conical bony cores which, in horned cattle, support the horns.

The horns are made up of a bony core ensheathed by a strong horny epidermal case, the material composing which is secreted by a deep-lying membrane similar to the keratogenous membrane of the hoof. The bony core becomes hollow by the extension into it of the sinuses of the frontal bone; hence such horned ruminants (oxen, sheep, goats, antelopes) are sometimes described as Cavicornia (hollow-horned). The horny sheath persists throughout life, growing with the bony core. The horny covering grows like any other part of the epidermis, or surface skin, its cells being secreted by that portion of the skin which is spread over the osseous cores of the frontal bones, completely enveloping the latter. This skin is richly supplied with blood-vessels.

The rings on the horn increase with age, the first appearing at two or three years; as age advances they get obliterated from various causes. In the bull the horns are short, thick, and powerful; in the

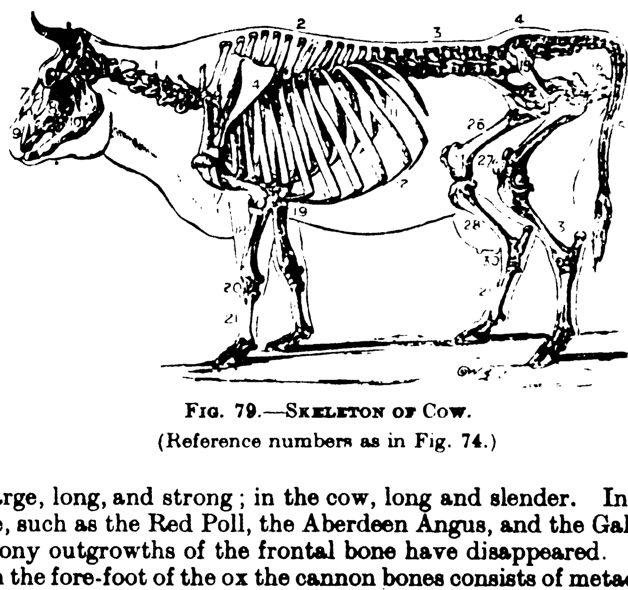


FIG. 79.—SKELETON OF COW.
(Reference numbers as in Fig. 74.)

ox, large, long, and strong; in the cow, long and slender. In polled cattle, such as the Red Poll, the Aberdeen Angus, and the Galloway, the bony outgrowths of the frontal bone have disappeared.

In the fore-foot of the ox the cannon bones consists of metacarpals 3 and 4 equally developed, but joined-together along their inner faces. The digits of these metacarpals are fully developed, and are not joined to each other. As each carries its own separate hoof, the "cloven hoof" is thus formed, which has been evolved with reference to walking and climbing on irregular surfaces. The hind-foot is similarly constructed

The skeleton of the sheep resembles that of the ox in all essential characters.

The cervical vertebræ of the pig (Fig. 80) are, for its size, shorter, wider, and stronger than those of other farm animals. The skull has a prominent "occipital" ridge or crest. At the free end of

the middle bone of the nose, a small "floating" bone, called the "prenasal ossicle," or "scooping bone," strengthens the snout. The mandible is so articulated to the skull that the jaw moves freely in all directions. The sternum is flat. Metacarpals 2, 3, 4, 5 are all distinct, as are metatarsals 2, 3, 4, 5, but the second and fifth do not reach the ground, and merely form "dew claws" (Fig. 80). They prevent the animal from sinking too deeply into soft ground.

The skeleton of the dog, like that of all Carnivora or flesh-eating animals is characterized by having the ulna and fibula well developed, by there being four or five digits on each limb (5 in fore and 4 in hind is the usual arrangement for all Carnivora) and by the phalanges bearing claws. There are no clavicles.

Dentition.—The study of the teeth is of especial interest to agriculturalists and animal breeders as the variation in their number and condition at different periods in the animal's life is taken advantage of in order to determine the age. In most mammals there

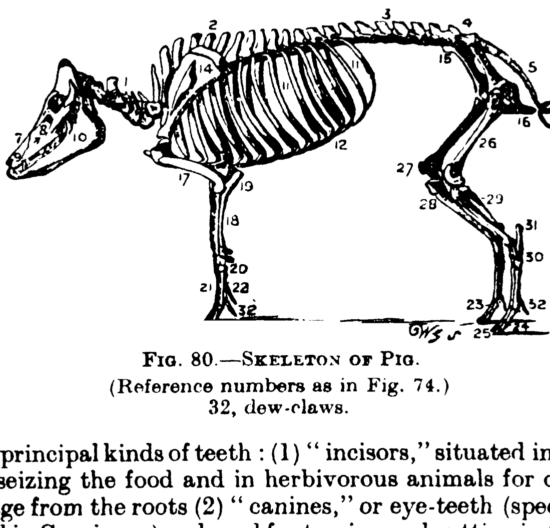


FIG. 80.—SKELETON OF PIG.
(Reference numbers as in Fig. 74.)
32, dew-claws.

are three principal kinds of teeth : (1) "incisors," situated in front and used for seizing the food and in herbivorous animals for cutting off the herbage from the roots (2) "canines," or eye-teeth (specially well developed in Carnivora) and used for tearing and cutting in the mouth and (3) molars or grinders (usually divided into premolars and true-molars—the latter being unrepresented in the first or "milk" set—between which the food is ground and masticated. The teeth are arranged symmetrically in equal numbers on each side and their number and arrangement can be expressed shortly in a "dental formula." Thus, the dental formula for a horse with a full mouth is as follows :—

$$\text{Incisors}\ \frac{3-3}{3-3}\quad \text{Canines}\ \frac{1-1}{1-1}\quad \text{Premolars}\ \frac{3-3}{3-3}\quad \text{Molars}\ \frac{3-3}{3-3}.$$

This means that there are three incisors on each side in each jaw, and similarly with the other kinds of teeth. The dental formula can be

written shortly for one side (the other side corresponc ng) as follows:

$$\frac{3133}{3133}.$$

The canines which are commonly called " tushes " in the horse are usually only present in the stallion. The premolars and molars in the horse are characterized by having complicated ridges of enamel running in different directions and separated by the softer cement substance, the whole tooth wearing with a rough surface which is admirably adapted for grinding or crushing the food. The incisors in the horse are at first vertical in both jaws but become oblique with advancing age. All the teeth are gradually pushed out from their sockets, the fangs becoming reduced in length ; at the same time the teeth are ground down through wear and tear, the dentine which occupies the central part of the tooth and is less dense than the enamel or cement, becoming exposed. By taking advantage of this fact the age of the animal can be approximately determined after it has acquired its full mouth of permanent teeth. In earlier life it is usual to ascertain the age by noting the number and arrangement of the temporary or milk teeth, there being two sets of teeth in the horse and other hoofed animals just as there are in man. The temporary teeth are smaller and usually whiter than the permanent ones and have a narrower neck. (The true molars are represented by the " wisdom teeth," in man and are not preceded by milk teeth, as already mentioned.)

The arrangement and state of the front teeth of the horse at different ages may be summarized as follows :—

Five months—Inner and middle milk incisors meet and corner ones are just through.

One year—Corner incisors meet. Altogether there are 12 temporary incisors, 12 temporary molars and four permanent molars which have recently appeared.

Two years—Milk incisors are all up and level.

Two and a half years—Front incisors (4) fall out and are replaced by permanent ones (4).

Four years—Middle incisors are out and permanent ones have appeared. Tushes begin to show in stallion. There are 24 permanent molars.

Four and a half years—Corner permanent incisors appear.

Five years—Permanent incisors are all level. Tushes are quite out of gum and may be up.

Six years—Cement of front incisors has nearly gone.

Thirteen years—Central enamel of front incisors has nearly gone.

The dental formula of the ox and sheep is as follows :—

$$\mathrm{I}\,\frac{0-0}{3-3}\quad \mathrm{C}\,\frac{0-0}{1-1}\quad \mathrm{PM}\,\frac{3-3}{3-3}\quad \mathrm{M}\,\frac{3-3}{3-3}.$$ The molars and prémolars bear crescentic ridges which are characteristic of ruminants. Hence they are called " selendont " (the reference being to the crescent

moon). There are no incisors or canines in the upper jaw, these being replaced by a dental pad against which the lower teeth bite. The permanent incisors are much larger and broader than the milk teeth and are known in the ox as the "broad teeth." The canine is often regarded as a corner incisor (which it in every way resembles), and on this view the canines are unrepresented.

The arrangement of the front teeth of the ox at different ages is as follows :—

One year—Milk incisors only (all "baby teeth").

One and a half years—Central incisors are up (two "broad teeth").

Two and a half years—Central and middle incisors up (four "broad teeth").

Two and three quarter years—All incisors up (six "broad teeth").

Three and a half years—Canines up (eight "broad teeth").

An animal with milk teeth only is described as a "beefling" or "baby beef" animal.

The arrangement of the front teeth of the sheep at different ages is as follows :—

At birth—No teeth.

One month—Full mouth of temporary incisors.

One and a quarter years (Shearling)—Two central incisors.

One and a half years—Two middle incisors (four altogether).

Two and a half years—Two lateral incisors (six altogether).

Three years—Two corner incisors (or canines). (Eight front teeth altogether.)

In the pig the dental formula is as follows :—

$$I\,\frac{3-3}{3-3}\quad C\,\frac{1-1}{1-1}\quad PM\,\frac{4-4}{4-4}\quad M\,\frac{3-3}{3-3}.$$

The pig has the full mammalian dentition of forty-four teeth. The canines are enlarged to form the tusks, especially large in the male. The molars and premolars are provided with knobs or bosses (typically four) instead of crescentic ridges ; such teeth are called "bunodont." It is to be noted that the teeth develop in a different order from that of the other animals mentioned.

At birth—Two temporary teeth on each side in each jaw (corner incisors and canines).

Three months—Full mouth of temporary teeth.

Nine months—Two permanent teeth on each side in each jaw (corner incisors and canines but the latter are only through the gums).

Thirteen months—A pair of permanent central incisors in each jaw.

Eighteen months—A pair of permanent lateral incisors in each jaw (full mouth).

The dog has the following dental formula :—

$$I\,\frac{3-3}{3-3}\quad C\,\frac{1-1}{1-1}\quad PM\,\frac{4-4}{4-4}\quad M\,\frac{2-2}{3-3}.$$

The canine teeth are especially well developed, as in other Carnivora. For the purpose of tearing flesh the molars are also modified, especially the last premolar in the upper and the first molar in the lower jaw ; these have sharp scissor-like blades which come together as the jaw closes, and are known as " carnassial " teeth.

Muscular System.—The skeleton affords support to the soft parts of the body. These soft parts consist very largely of flesh or muscle. A muscle is made up of " fibres," and most of the muscles concerned in the movements of the limbs are spindle-shaped, that is, swollen in the middle and tapering at the ends. Such muscles, under suitable conditions, " contract," by which is meant they become shorter and thicker, so that their two ends are brought nearer to each other. As one of these ends (the " origin ") is usually relatively fixed, the result is that whatever is attached to the other end (the " insertion ") is compelled to move. In this way the movements of the limbs are brought about. The rough surfaces, or ends, with which some bones are provided (*e.g.*, the third trochanter, p. 429), serve to facilitate the attachment of muscles, or of the fibrous cords or tendons, in which the muscles often terminate.

Metabolism.—As in the case of plants, so also with animals the complete series of chemical changes going on in the living substance are grouped together under the term " metabolism." It is characteristic of living matter, as contrasted with non-living, that there should be a constant change of substance, although the outward form remains much the same, apart from modifications due to growth. But whereas in a green plant the material taken in consists of carbon dioxide, water, and simple mineral substances, an animal requires complex food of organic nature, and all animals, in the long run, are dependent upon green plants for their supply of such food ; that is to say, carnivorous animals are dependent upon herbivorous ones which in turn obtain their supply of energy from plant food. This is because an animal cannot, like a green plant, use the energy derived from sunlight to manufacture simple non-nitrogenous organic compounds from water and carbon dioxide. In an animal these complex substances of which the body is built up are broken down into simpler ones by a process of oxidation, the oxygen necessary for the process being absorbed in the act of respiration.

Digestive System.—The digestive organs of an animal are those which are concerned with the conversion of the ingested food into a condition such as to render it capable of being absorbed into the circulating blood or lymph in which the nutritive material is carried to the various parts of the body according to the animal's needs. There are three principal classes of foodstuffs—proteins, carbohydrates and fats—to which must be added certain essential minerals which enter into the composition of some part of the body, certain accessory food substances known as vitamins, and water. The consideration of these various substances is dealt with in Chapter XIX.

In all the higher animals the digestive organs consist of a long tube, the alimentary canal or gut, which traverses the entire length

of the body, and of certain glands connected with it. The successive regions of the canal are—"mouth," "pharynx," "gullet," "stomach," "small intestine," "large intestine," ("cæcum," "colon," "rectum") (Fig. 80A), and these will now be separately considered, while at the same time the course of the food through the body will be traced.

Commencing at the mouth, the food is crushed between the molar teeth, the muscles of the tongue and the cheeks continually guiding it to where it can be chewed. Meanwhile the salivary glands that open into the mouth pour out a fluid called "saliva" which moistens the food, and every now and again a bolus is moulded and passed to the back of the mouth behind a fleshy curtain called the "soft palate" into a dilatation known as the "pharynx," with which the nasal cavities are also connected. From the pharynx a distensible tube—the "gullet" or "œsophagus"—extends through the thorax,

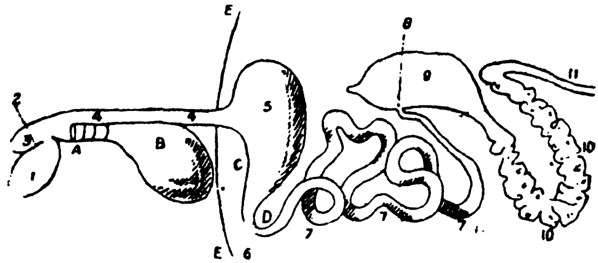


FIG. 80A.—DIAGRAMMATIC REPRESENTATION OF THE ALIMENTARY CANAL (the intestinal parts proportionately much shortened.)

1, mouth.
2, soft palate.
3, pharynx.
4, œsophagus or gullet.
5, stomach.
6, pylorus.
7, small intestine.
8, ileo-cæcal valve.
9, cæcum.
10, colon.
11, rectum.

A, trachea.
B, position of lungs.
C, region of liver.
D, region of pancreas.
E E, position of diaphragm.

at the hinder end of which it pierces the diaphragm (a musculo-membranous partition separating the thorax and abdomen). In the abdominal cavity the gut suddenly enlarges to form the stomach, a large bag, which in some animals occupies a considerable part of the cavity. The exit from the stomach is by a narrow opening, called the "pylorus," into the small intestine, a narrow, thin-walled tube, many times the length of the animal to which it belongs. Hence it is doubled up in an intricate fashion in order that it may be accommodated within the restricted space contained in the abdominal cavity. Nor is it merely doubled upon itself many times—it is also slung up and kept in position.

Take a pocket-handkerchief and double it lengthwise, keeping the two edges uppermost. Within the fold, at the bottom, place a length of india-rubber tubing, so that it reposes between the two adjoining

faces of the handkerchief. Now gather together, or pucker up, the free margins of the handkerchief that are in contact above, and, as a result, the india-rubber tubing will be coiled or doubled on itself. It is in a somewhat similar way that the long intestinal tube is packed and slung in the abdominal cavity. The place of the handkerchief is taken by a delicate transparent sheet of "connective tissue," called the "mesentery," which is doubled on itself, so as to form a loop in which the intestinal tube reposes, whilst, between the two faces of the mesentery, which adhere together, delicate tubes or vessels pass to and from the intestine. The transparent filmy material—here and there laden with fat—which is often spread out upon a dish of pig's fry, gives a good idea of the nature of the mesentery. It should be added that the mesentery is continuous with a moist membrane, the "peritoneum," that lines the abdominal cavity.

Traced onwards, the small intestine comes to an abrupt termination by opening suddenly into a much wider tube, called the large intestine, and consisting of three regions: firstly the "cæcum," or blind gut; next, the "colon"; and, finally, the "rectum," which opens externally by the vent or "anus."

In the horse the cæcum is used largely as a reservoir for water, its contents being normally very fluid. The immense colon in the horse is used for the digestion of cellulose or fibre and corresponds functionally to the rumen in the ox, but the latter organ is at the extreme fore end of the gut.

It is popularly said that oxen and sheep have four stomachs, but in reality the three anterior ones, of which the first is the rumen or paunch, are enlargements of the gullet; indeed, in the young ruminant the first three compartments are undeveloped and do not function. The names of these compartments in the order in which the food traverses them, are :—

1. The "rumen" or paunch (the "tripe" of butchers is chiefly this).
2. The "reticulum" or honeycomb stomach.
3. The "omasum," "psalterium," or manyplies.
4. The "abomasum," reed, or rennet stomach.

The capacity of the stomach in cattle is enormous, amounting to from fifty to sixty gallons, and filling the greater part of the abdominal cavity. The paunch alone is nine-tenths of the entire volume of the stomach, the remaining three divisions constituting a mere chain on the front left side of the paunch. In sheep and goats, though absolutely smaller, the paunch is relatively as large as in the ox. The fourth division, or abomasum, is the only part of the ruminant stomach, the internal lining membrane of which secretes gastric juice. It is called the rennet stomach, because it is the fourth compartment of the calf's stomach, which is salted and preserved, in the form of "vells," to furnish natural rennet for use in cheese-making. The secretion of the gastric or peptic glands (p. 440) supplies the rennet.

Ruminants can stow away, in the rumen or paunch, a huge quantity of vegetable food. This, at a suitable time, is regurgitated,

into the mouth, where it is mixed with the juice of the salivary glands, and slowly reduced to a fine condition between the teeth—this is called "chewing the cud," or rumination. Passing again down the

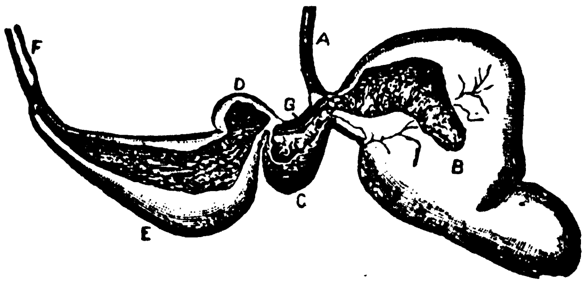


FIG. 81.—RUMINANT STOMACH (sheep).

A, gullet or œsophagus.
B, rumen or paunch.
C, reticulum or honeycomb.
D, omasum or liber.
E, abomasum or rennet stomach (the true digestive chamber).
F, small intestine.
G, gutter made by a fold of the lining membrane of C.

gullet, the masticated food is this time directed along a gutter (Fig. 81, G), through the third division, which acts as a strainer, and so into the fourth division of the stomach—the reed, rennet stomach, or abomasum. The glands imbedded in the lining of this compartment of the stomach pour out abundant gastric juice (p. 441) upon which the food, which is at the same time kept in continual motion by the peristaltic contractions (p. 441) of the wall of the organ. Through a narrow aperture, the pylorus, the material leaves the ruminant stomach, and pursues its course along the intestines, as in horses and pigs. The peculiar digestive organs of ruminants no doubt gradually came into existence as a means of protection, in a region where powerful carnivorous animals abounded. They enabled food to be rapidly swallowed, after which some place of security was sought, where the processes of chewing and digestion could be carried out at leisure. Existing wild ruminants—*e.g.*, antelopes—still benefit by this arrangement.

Of the food which a mammal eats, part is digested—that is, converted into a soluble form fitted for absorption into the blood. The remainder, which escapes digestion, passes through the canal or tube which has been described, and is finally ejected from the body as dung. The course taken by such an undigested particle is, therefore, mouth, pharynx, gullet, stomach, small intestine, cæcum, colon, rectum.

The Digestive Juices.—Connected with the alimentary canal are certain structures, called "glands," which possess the power of manufacturing, out of the blood which flows through them, special juices, which they pour out in the form of secretions. Opening into the mouth are the salivary glands, already referred to (p. 438), and innumerable minute tubular gastric or peptic glands are imbedded in

the lining of the stomach (abomasum in ruminants). They secrete the gastric juice. In the abdominal cavity are two very important glands, the liver, which secretes the "bile," and the pancreas (or sweetbread), which secretes the "pancreatic juice." Besides this, there are vast numbers of microscopic tubular intestinal glands in the lining of the small intestine. Their secretion is known as "intestinal juice."

The liver is the largest gland in the body, and is packed, as it were, between the diaphragm and the stomach (Fig. 80A, C). By turning back its lobes there may be exposed an olive-green pear-shaped body, called the gall-bladder (absent in the horse), connected with a tube that runs from the liver to the beginning of the small intestine, into which it opens. This tube is the "bile duct," and along it flows the bile, a golden-coloured liquid, which the liver prepares from the blood, and which is poured in amongst the mass of food-material undergoing digestion in the small intestine. When there is not much food in the small intestine the process of digestion is less active, there is a diminished demand for bile, and the fluid is then temporarily stored up in the gall-bladder.

The pancreas, or sweetbread, is a pale-coloured gland, which is distributed in a patchy fashion upon that portion of the mesentery which adjoins the stomach and (Fig. 80A, D) the U-shaped first part ("duodenum") of the small intestine. The juice which it secretes is poured by means of a narrow tube, the "pancreatic duct," into the small intestine, in the same way as the bile duct pours in bile.

It is now apparent that, in its passage through the alimentary canal, the food is subjected to the action of the saliva, the gastric juice, the pancreatic juice, the bile, and the intestinal juice, the joint effect of all of which is—in the case of a healthy animal—to dissolve such parts of the food as can be used for repairing waste and effecting growth. But an important question here arises. Why does food travel along the alimentary canal? How, again, can a horse or an ox pass its food along when, as in grazing, its head is lower than its stomach?

If a rabbit, or a rat, or any other mammal, is killed, laid on its back, and its abdomen opened immediately after death, the intestines are seen to be in continual writhing movement. During life, this wave-like motion is incessantly in progress throughout the entire length of the gut from the gullet onwards. A kind of gripping contraction takes place, travels onwards, and is at once followed by another, the result being that the food is propelled in the desired direction, and, in the stomach, undergoes a motion like that of churning. This movement in the gut is called "peristaltic contraction," and it is the work of the muscular fibres which form the middle coat of the wall of the canal. The motion is involuntary—that is, it is not under the control of the will, and goes on unceasingly.

With such exceptions as sugar, most of the solid constituents of the foods of animals are practically insoluble. By the process of digestion, however, these ingredients are brought into a form in which

they can be absorbed by or taken into the blood. The chief agents in this process are ferments, complex proteins, of which minute quantities are contained in the digestive juices, bile excepted. Ferments are of great physiological importance, because they are able to bring about a very large amount of chemical change without being appreciably used up themselves.

The saliva which is poured into the mouth not only lubricates the food, thus softening it and rendering it easy to swallow, but also exerts a chemical action. It contains a very small quantity of a ferment known as "ptyalin." This converts starch into sugar which is readily soluble, and in the dissolved state easily diffuses through a moist membrane. Ferments which act on starch in this way are said to be "amylolytic"—*i.e.*, starch converting.

Gastric Juice is slightly acid, owing to the presence of a small amount (·2 per cent.) of free hydrochloric acid, which apparently acts as a germicide, destroying deleterious bacteria, etc., that happen to be swallowed with the food. This secretion contains two ferments: (1) "rennin," which curdles milk, and (2) "pepsin," which converts the comparatively insoluble proteins into soluble diffusible proteins called "peptones." Rennet owes its peculiar properties to the presence of rennin (see p. 439). Because of its action on proteins pepsin is known as a "proteolytic"—*i.e.*, protein-dissolving ferment. Gastric juice has no effect upon starches or fats. But it helps to break up fatty tissue in that it dissolves the connective tissue which binds the fat vesicles together.

The bile, owing to its strongly alkaline character, plays an important part in emulsifying the fats—that is, in reducing them to a very fine condition, in which their particles are capable of being suspended in the body of a liquid. New milk is a good example of an emulsion, but, after the cream has been allowed to rise, it is hardly possible, by any means, again to mix up the fatty particles with the liquid as thoroughly as before. So, when oil is poured on water in a bottle, it requires violent shaking to mix the two thoroughly—that is, to make an emulsion. The addition of a little carbonate of soda or similar alkaline substance renders this easy.

The pancreatic juice carries on the work begun by other digestive juices—saliva, gastric juice, bile. It is an alkaline fluid, containing three ferments: (1) "amylopsin," which is amylolytic; (2) "trypsin," which is proteolytic; and (3) "steapsin," a fat-splitting ferment.

The amylopsin continues the work begun by the saliva of converting starch into sugar; the trypsin acts upon proteins and peptones, breaking them down to simple bodies called amino-acids, and the steapsin splits fats into glycerine and fatty acids. At the same time the alkaline constituents of the pancreatic juice assist the bile in emulsifying the fats.

It need only be said of the intestinal juice that its action is broadly speaking similar to that of other ferment containing substances and that it contains special ferments acting on various kinds of sugars.

The nett result of the chemical digestion described is to reduce a

large part of the starch, fat, and proteins of the food into soluble substances that are absorbed into the blood, as will be subsequently explained.

It also appears that a part of the cellulose which makes up so much of the food of the horse, ox, sheep, and goat, is converted into a soluble form within the alimentary canal. This, however, is not the work of the digestive juices, but is due to the ferment action of certain bacteria, more particularly in the colon.

Circulatory Organs.—It is clear that some arrangements are necessary to secure the distribution of digested food throughout the body, to carry waste products to the organs by which they are removed from the system, and also to maintain a uniform temperature. These duties are discharged by the circulatory organs, a set of tubes and other spaces containing the fluids known as blood and lymph, that serve as media of exchange, and are respectively contained in the blood system and the lymph system, which are best considered separately.

Blood System.—A drop of fresh blood, obtained by pricking a finger-tip (after tightly winding a piece of string round the base of the end-joint) should be examined under a high power of the microscope (Fig. 82). It will be seen to consist of a liquid ("plasma") and of innumerable very minute "corpuscles." These are of two kinds, red and white. The far more numerous red corpuscles are circular biconcave bodies, devoid of a nucleus (as in all mammals), and of a pale, reddish-yellow colour, owing to the presence of a complex substance, "hæmoglobin," resembling in some ways the green pigment (chlorophyll) of plants. When seen in bulk these corpuscles are red, and to them the characteristic colour of blood is due. They are of great importance in connection with respiration and may be regarded as oxygen-carriers.

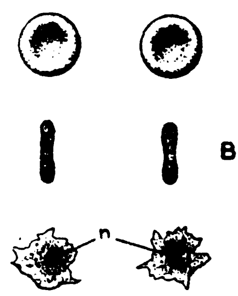


FIG. 82.—BLOOD CORPUSCLES.

Highly magnified.
A, red corpuscles, seen flatwise; their thin centres are darkly shaded.
B, ditto, seen edgeways.
C, white corpuscles.
n, nucleus.

The white or colourless corpuscles ("leucocytes") are larger and much less numerous than the red ones, and if treated with very dilute acetic acid are seen to contain a nucleus. When kept at the temperature of the body they exhibit a constant change of shape, and crawl about from place to place. They are, in fact, wandering cells, which perform a variety of functions. One important use of the colourless corpuscles of the blood (and lymph) is to serve as a kind of territorial army, engulfing and digesting disease bacteria that have entered the system.

The blood moves or circulates through the body in a closed set of tubes, the organs of circulation of the blood, which comprise (1) the heart; (2) arteries; (3) veins; and (4) capillaries.

The heart, which may be regarded as a central force-pump, is a hollow muscle, formed of two independent halves, right and left. Each half is divided into a thin-walled anterior compartment, the "auricle," and a thick-walled posterior compartment, the "ventricle." The whole organ is enveloped in a delicate membrane, the "pericardium," forming a kind of double bag, with pericardial fluid between its two layers, and is lined internally by a similar kind of membrane, the "endocardium," flaps of which project inwards to form "valves." Such valves exist at the orifice between the auricle and the ventricle on each side, and also at the orifice leading out of each ventricle. The valves are so arranged as to permit the blood to flow from auricle to ventricle, and from ventricle outwards, but to prevent its passing in the opposite direction. In a state of healthy life, the blood in the left side of the heart is of a bright scarlet colour ("arterial blood"); that in the right side is of a dark purple hue ("venous blood").

The vessels, or tubes, which carry blood from the heart are called arteries; those which convey blood to the heart are veins. The arteries spring from the ventricles; the veins discharge into the auricles. As an artery is traced away from the heart it is found to branch continually, the branches themselves breaking up in a similar way. The subdivision is continued until extremely narrow thin-walled tubes, the capillaries, at length result, and these permeate every part of the body, except the epidermis and its appendages (hair, wool, horn, etc.), and the cartilages.

Traced onward, the capillaries are found to give origin to the smaller veins, which become confluent into larger and larger veins, through which the blood returns to the heart.

Without entering at any length into the details of the circulatory organs, the student may acquire a knowledge of the chief facts by following the course of the blood from the heart back to the place of starting. The names of the chief vessels and tubes through which the blood flows may be mentioned incidentally.

Starting, then (Fig. 83), with a particle in the scarlet blood of the left ventricle (1), it is driven by the contraction (beating) of the heart through the open "semilunar" valves into a strong elastic artery (2) called the "aorta." This curves round to the left, and while it sends a branch (3) towards the head, the main trunk extends backward (4) beneath the vertebral column, and eventually divides into two "iliac" arteries (beneath the ilia, p. 427) one of which supplies the right hind-leg, and the other the left. In due course the particle finds itself in a capillary (8), either in the pelvic region or in the limb. Hurried along in the current of the blood, it travels through the smaller veins, and ultimately reaches a great vein (9), the "posterior vena cava," which extends beneath the vertebral column alongside the aorta. This vein passes forward, pierces the diaphragm—as does the aorta in passing backward—and throws the particle into (13), the right auricle of the heart. The contraction of the auricle drives the particle past the open "tricuspid valves" into (14) the right ventricle,

the contraction of which propels it through the right "semilunar" valves into (15) the "pulmonary" artery, through the narrowing branches of which it reaches at length one of the blood capillaries in

The animal is supposed to be opened along the under or ventral side, and to be laid upon its back, so that the *left* of the animal is at the observer's right. The arrows indicate the direction of flow. The vessels along which *arterial* blood travels are unshaded (chyle flows through D); those which convey *venous* blood are represented by the full black colour. Notice that all the arteries *except* the pulmonary artery (15) carry arterial blood, and all the veins *except* the pulmonary veins (16) venous blood. In other words, whilst in the *systemic* circulation the arteries convey arterial blood and the veins venous blood, in the *pulmonary* circulation this state of things is reversed.

H, heart (17, 13, auricles; 1a, 14, ventricles)
L, L, lungs.
T, trachea, or windpipe.
B, B, bronchi.
K, kidney.
I, I, intestinal canal.
LR, liver.
A, lacteals.
D, thoracic duct.
P, blood vessels carrying blood, and absorbed peptones, sugar, etc., from small intestine to portal vein (11).
1, left ventricle.
2, aorta.
3, artery supplying head and fore-limbs.
4, dorsal aorta.
5, hepatic artery supplying liver.
6, artery supplying intestines.
7, renal artery supplying kidney.
8, blood capillaries.
9, posterior vena cava.
10, renal vein.
11, portal vein.
12, hepatic vein.
13, right auricle.
14, right ventricle.
15, pulmonary arteries.
16, pulmonary veins.
17, left auricle.
18, blood capillaries.
19, vein from fore part of body
20, anterior vena cava.

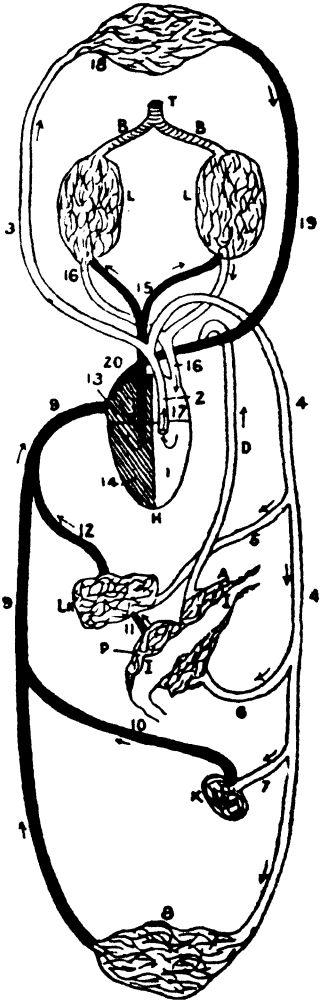


FIG. 83.—DIAGRAMMATIC REPRESENTATION OF THE CIRCULATORY SYSTEM IN A MAMMAL.

the air-cells of (L) the lungs (Fig. 84). Thence it travels through the smaller veins of the lungs, and ultimately passes into (16) one of the pulmonary veins, which enter (17) the left auricle of the heart,

whence the particle is driven past the open "mitral" valves into (1) the left ventricle, and so regains the point from which it started.

The contraction of the heart is rhythmic, or regular. First the auricles contract together, next the ventricles, and then there is a pause, after which the contractions are repeated. It is the volume of blood suddenly thrown into the aorta by the ventricular contraction, and distending the walls of that elastic vessel, which produces the pulse. The number of pulsations corresponds, therefore, with the beating of the heart. Arteries are, as a rule, deep-seated, but the pulse can be felt at a few places where an artery of some size passes along the surface of a superficial bone; in horses, on the border of the lower jaw, or inside the elbow; in cattle, under the tail, or on the middle of the first rib. As the pulse takes time to travel along the arteries, it is felt later in, say, the foot, than at the temple. The normal pulse of full-grown animals is, in the horse, about 36 per minute; in the ox, 55; in the sheep and pig, 75. The pulse rate increases with exercise and decreases with rest. In young animals it is more rapid, and when an animal is feverish it is more frequent.

FIG. 84.—LUNGS OF SHEEP, seen from below.

1, right lung.
2, left lung.
3, trachea or windpipe.
4, heart.
5, carotid arteries, right and left.
6, vena cava posterior.

As the united sectional area of the arteries is much greater than that of the aorta, which supplies them, the pulse dwindles, and in the veins it has disappeared altogether. Indeed, so little is the effect of the ventricular contraction felt in the veins that they are provided with valves, arranged in such a way as to flap against the walls, while the blood is flowing, as it should, towards the heart, but to float across and bar the path should the blood attempt to flow in the reverse direction. By pressing the lower end of the "jugular" vein, which extends along the groove on either side of the neck of a horse, it is possible to "fill the jugular"; for the moment, the blood is prevented from flowing on towards the heart, and the knotted appearances show the positions of the valves. We can understand from the above why the blood flows from a cut artery in jets or spurts, and from a cut vein in a steady but slower fashion. And it is worth remembering that bleeding from an artery can be arrested by pressure on the side nearer to the heart, while the opposite is true in the case of a vein.

It is now possible to answer two important questions. How does the dark (venous) blood in the right side of the heart differ from the scarlet (arterial) blood in the left side? What is the cause of this difference?

From what has been already stated, it is obvious that the change from dark blood to scarlet blood takes place during the passage from the right ventricle to the left auricle—that is, while the blood is passing through the capillaries of the lungs—this is called the "pulmonary" circulation. On the other hand, the blood is changed from scarlet to dark purple during its course from the left ventricle to the right auricle—that is, in the capillaries of parts of the system other than the lungs—this is called the "systemic" circulation. The chief difference between the scarlet blood and the dark blood is that the former contains more oxygen and less carbon dioxide than the latter. If a vein is opened on the surface of the body, blood that is dark purple in colour flows from it. But it immediately becomes scarlet because, exposed to the air, it absorbs oxygen.

The scarlet blood that leaves the left ventricle is purer than the dark blood on the other side of the heart. In its passage through the capillaries of the system, however, the blood performs certain work. It carries material where it is required, and in this way it builds up or repairs the tissues, which it also supplies with oxygen. But it does more than this, for in all parts of the body waste is going on, and the products of such waste are swept away in the blood, to be carried to organs by which they are excreted, or removed from the system.

It is important to realize that the arteries and veins, especially the former, possess comparatively thick walls, through which diffusion cannot take place. The size or calibre of these vessels can be enlarged or diminished, owing to decreased or increased contraction of a muscular layer in their walls, and the supply of blood to a particular part can therefore be adjusted. Such adjustment is controlled by the nervous system.

The actual exchange of material between the blood and the living substance of the body takes place in the capillaries, by diffusion through the excessively thin walls of these microscopic vessels. At the same time the maintenance of an equable and constant temperature in all parts of the body is rendered possible.

Lymph System.—Everyone must have noticed the clear fluid that collects underneath a blister on the hand or foot. This is a local accumulation of lymph, a fluid that occupies certain large spaces in the body, such as the abdominal cavity, the pericardial cavity, and the pleural cavities, and also fills up the minute irregular crevices in the various tissues. Microscopic examination shows that lymph consists of white or colourless corpuscles floating in liquid plasma.

Connected with the lymph-spaces are a number of delicate lymphatic vessels, resembling small veins in structure, and ultimately opening into a slender tube, the thoracic duct, lying just below the backbone in the front part of the abdomen and in the thorax, and communicating with the great veins on the left-hand side at the base of the neck (Fig. 83, D). At this point lymph is constantly flowing into the blood. The lymphatic vessels of the intestine have received the special name of "lacteals" (*L. lac*, *lactis*, milk), because after a meal containing fat they are seen to be filled with a

milky-looking fluid. Here and there in the course of lymphatics rounded nodule-like bodies may be observed, a well-known example being the "pope's eye" in a leg of mutton. These are the lymphatic glands, which may be regarded as manufactories of colourless corpuscles.

Breathing or Respiratory Organs.—The windpipe ("trachea") runs from the pharynx—below the gullet—along the ventral side of the neck into the thorax, where it divides into the right and left "bronchus," going to the corresponding lung.

Each of these organs is invested in a sort of double bag, comparable to the pericardium. The presence of a small quantity of lymph between the "pleuræ," or membranes forming the walls of this bag, enables the lungs to glide over the inner surface of the thorax without friction as the respiratory movements take place. The disease known as "pleurisy" results from inflammation of the pleural membranes, and is associated with more or less friction and pain.

If we follow a bronchus into its lung we shall find that it divides in a branching manner into smaller and smaller tubes, the smallest and most delicate of these being called "bronchial tubes," inflammation of which causes bronchitis. (It may be noticed in passing that the termination "itis" (met with in the names of many diseases) means "inflammation," a condition associated with the local accumulation of colourless corpuscles for the purpose of attacking disease germs).

A bronchial tube ends in a group of minute "air-sacs," the delicate walls of which are closely surrounded by a close net-work of capillary blood-vessels. Inflammation of the lungs or pneumonia is an inflammatory disease of the bronchial tubes and air-sacs, and is not infrequently associated with pleurisy, in which case the term pleuro-pneumonia is employed. The mischief is caused by the entry of certain bacteria.

The greater part of the spongy substance of the lungs is made up of the bronchial tubes, with their air-sacs. It is through these that breathing or respiration takes place. This consists of the taking in of pure oxygen, while at the same time the waste product, carbonic acid gas or carbon dioxide, is excreted or removed from the system. In the animal there is, so to speak, an exchange of material between the dark impure blood in the capillaries of the air-sacs and the air which these contain. Oxygen diffuses from the air into the blood, and carbon dioxide from the blood into the air. The latter also receives a good deal of water vapour, and a minute quantity of nitrogenous waste, while at the same time its temperature is raised. We consequently find that the air breathed out or exhaled differs considerably from the air breathed in or inhaled.

The blood going to the lungs is said to be impure—*i.e.*, it contains relatively little oxygen and a large amount of carbon dioxide. After a great deal of the latter has been got rid of in the lungs, and a fresh supply of oxygen taken up, it becomes pure blood, and flows into the left auricle of the heart. A word is necessary as to the marked

difference in hue between these two kinds of blood. As already mentioned the red corpuscles owe their colour to the presence of the complex substance termed hæmoglobin. This is capable of taking up a certain amount of oxygen into loose chemical combination, and then becomes "oxyhæmoglobin," which is bright scarlet. Hence the colour of pure or arterial blood. Hæmoglobin of this kind, however, easily parts with its loosely combined oxygen, and then becomes reduced to hæmoglobin, which is dark purple. The oxyhæmoglobin of the pure blood which is pumped by the left ventricle of the heart to the capillaries of the body gives up its loosely combined oxygen to the tissues, and becomes hæmoglobin. Hence the purple colour of impure or venous blood. We see, therefore, that the red corpuscles play the part of oxygen-carriers. They take up oxygen in the lungs and supply it to the tissues.

It is clearly necessary for the air in the lungs to be constantly renewed, and observation of a living animal shows that respiratory movements are always taking place. During the breathing in or inhalation of air the volume of the thorax is increased, the lungs expand, and air flows into the larger air-tubes. The opposite takes place during the breathing out or exhalation of air. It is important to note that renewal of air in the bronchial tubes and air-sacs is effected by gaseous diffusion. The thorax is increased in volume by movements of the ribs and breastbone, by the contraction of "intercostal" muscles running obliquely between the ribs, and by contraction of the diaphragm. This is really a flat muscle, with a fleshy margin ("skirting steak" of butchers) and fibrous or tendinous centre. There are also important muscular bands, the "pillars of the diaphragm," running obliquely upwards and backwards from the dorsal part of this partition and becoming attached to the backbone. During a state of rest the margin of the diaphragm is convex towards the thorax. When air is breathed this margin becomes flattened by contraction of its muscular fibres.

When air is breathed out the thorax is diminished in volume, largely owing to the return of the ribs and sternum to their former position, as the result of elasticity, while at the same time the diaphragm ceases to contract, and once more becomes convex towards the thorax. The mechanical part of respiration or breathing is thus carried on, and the behaviour of the thorax may be likened to that of a pair of bellows working through the nozzle only.

During the passage of the blood from the left side to the right side of the heart the oxygen is largely occupied in oxidizing particles of carbonaceous matter in the blood itself, while oxidation is also constantly going on in the living substance of the body. Since oxidation is accompanied by heat, it will be understood how the heat of the body is maintained.

Excretion.—The term is applied to the process of getting rid of the waste products formed by metabolism, and organs which do this work are known as excretory organs. Since the lungs eliminate carbon dioxide and water from the system they obviously take part in

excretion, and the liver is also an important excretory organ, for bile is really a waste product, though it aids the process of digestion before leaving the body. The remaining excretory organs are the skin and kidneys.

THE SKIN, besides being an excretory organ, has an important function in regulating the temperature of the body through its blood supply and through the secretion of sweat. When the skin is congested, as after exercise or in a high surrounding temperature, heat is irradiated off from it in greater amount. The blood supply to the skin, as to the other parts of the body, is under the control of the nervous system, and when heat is produced in the body by muscular work or is augmented from outside (as in a high temperature), the quantity of blood flowing to the skin is increased, and a greater amount of heat is conducted or irradiated off. In this way the body temperature is kept approximately constant. If, however, the exercise is severe or the surrounding temperature is very high, a second heat regulating mechanism comes into play, and this is the secretion of sweat through the evaporation of which further heat loss is brought about. Such animals as the horse, which is provided with very numerous sweat glands, are able to maintain a constant body temperature easily, but in species with comparatively few sweat glands, such as the ox, sheep and pig, there may be, after exercise, a considerable rise of temperature resulting in distress. The sweat glands are also definitely excretory and their secretion contains a small amount of saline matter. It is for the salt upon it that a calf or a cow will lick a man's hand with its rough tongue. As horses perspire freely, it is desirable to keep their skins clean and free from dust, so that the action of the skin may not be impeded. This object is effected in grooming.

THE KIDNEYS are the chief organs of nitrogenous excretion. They are situated in the dorsal part of the abdominal cavity, immediately below the backbone. To protect them from violent shocks, each is embedded in a soft semi-fluid cushion of fat, which in the carcass of an ox or a sheep is called "suet." Each kidney receives blood by a short "renal artery," given off (Fig. 83, 7) by the dorsal or abdominal aorta, and returns its blood by a "renal vein" into the "posterior vena cava." The kidneys are made up of a great number of microscopic "urinary tubules," intimately related to a complicated set of capillary vessels, from the blood circulating in which they remove the constituents of the urine. These include the nitrogenous waste products known as "urea," "uric acid," and "hippuric acid," a large amount of water, and certain saline matters. It is because of the presence of nitrogenous waste that urine has a high manurial value, and that litter is spread in stables and byres to absorb this liquid, so that it may be used upon the land to promote the growth of crops.

The blood that leaves the kidney differs from the blood that enters it in that it has lost all the ingredients which go to form the urine, and so far as nitrogenous waste is concerned it is the purest blood in the body. The excretion of urine by the kidneys is constantly going on,

so that some means of getting rid of it are necessary. It continually trickles away from each kidney along a tube called the "ureter." The two ureters open into a thin-walled, elastic, distensible bag, the "urinary bladder," situated in the hinder part of the abdomen. From the bladder there issues a tube, the "urethra," through which the contents of the bladder are periodically discharged.

The lungs, liver, skin and kidneys are thus seen to be sources of loss to the blood. Water is lost at each of them, whilst the lungs are specially distinguished by the loss of carbon dioxide, and the kidneys by the loss of saline matters, urea, and hippuric acid.

With such waste always going on, it remains to inquire how the animal body is sustained, and by what means it is prevented, not only from wasting away, but is, on the contrary, caused to increase in size and weight. To answer this inquiry it is necessary to return to the food in the alimentary canal.

The Absorption of Digested Materials.—It has been seen that the effect of the digestive juices is to break up all food-stuffs into three main portions: (1) the dissolved nitrogenous matters and sugar; (2) the emulsified fats; and (3) an indigestible residue. The last-named part, consisting largely of coarse fibre, travels through the intestinal canal, and, mixed with some of the intestinal secretions, is passed away in the form of excrement, which, in the case of horses and pigs and stall-fed cattle, usually finds its way to the dung-heap, whence it is returned to the soil.

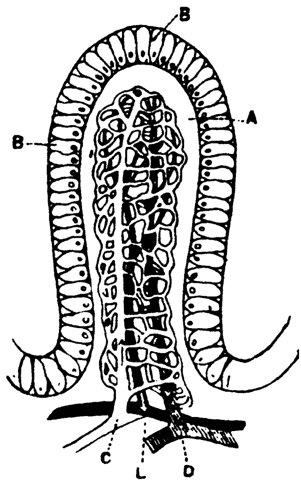


FIG. 85.—DIAGRAM OF A VILLUS OF THE SMALL INTESTINE.

A, body of the villus.
B, external covering of epithelium cells.
C, the small artery entering the villus, and breaking up into capillaries, which re-unite to form—
D, the small vein which leaves the villus;
L, the lacteal radicle which occupies the middle of the villus (solid black).

The dissolved matters and the emulsified fats are, on the other hand, taken up by the blood, and can thus be transported to all parts of the body. The absorption of digested materials by the blood is effected chiefly by the villi of the small intestine. Each villus is a minute club-shaped structure, projecting inwards from the internal lining membrane of the intestine. It is covered (Fig. 85) by a layer of delicate cells surrounding a fine network of blood capillaries, originating in a minute artery which enters the villus, and converging upon a small veinlet which leaves it. Within this network is a branching lacteal radicle, opening into a lacteal vessel which passes away from the villus.

Myriads of such villi line the internal surface of the small

intestine. Their blood-vessels derive their blood supply from the aorta, whilst all the veinlets which emerge from the villi become confluent, and pour their blood ultimately into a vessel called the portal vein, which passes into the liver (Fig. 83, 11). There, unlike the great majority of veins, the portal vein breaks up, and the blood it contains is submitted to the action of the cells of the liver. The liver also receives a supply of arterial blood through the hepatic artery, which derives its blood from the aorta (Fig. 83, 5). Without stopping to inquire into the minute structure and functions of the liver, it may be stated that this gland is drained of its blood by the hepatic veins (Fig. 83, 12), which open into the posterior vena cava, this latter passing directly into the right auricle of the heart. Hence the blood that travels through the villi of the intestines passes, by way of the liver, into the heart.

The blood that leaves the intestinal villi is, however, different from that which enters them. Most of the dissolved products of digestion ooze through the delicate covering of the cells which envelop the villus much as a thimble covers the end of the finger, and the solution further diffuses through the extremely thin walls of the blood capillaries within the villus. Consequently the blood that flows from the villi of the intestinal walls carries with it the dissolved amino-acids, sugar, salts and soaps, that are derived from the food, together with most of the water taken in at the mouth.

But what becomes of the minute particles of emulsified fat that exist in the small intestine? These particles are split by ferment action into fatty acids and glycerine, which are taken up by the cells (Fig. 85, B), covering the villus, and find their way, not into the blood capillaries, but into the lacteal radicle which the blood capillaries surround. Here they are recombined into globules of fat. The lacteal vessels which emerge from the villi become confluent, and ultimately pour their milky-looking contents, called "chyle," into the posterior end of the thoracic duct (Fig. 83, D), ultimately reaching the right auricle of the heart.

Though the villi of the small intestine are the most active seats of absorption of digested materials, some amount of absorption of dissolved matters is begun through the blood capillaries in the walls of the stomach. Absorption is also continued, to a greater or less extent, throughout the intestinal tube. The rapidity with which absorption is capable of being effected is well illustrated in the instant alleviation of thirst which follows upon the taking of water into the stomach, whence it promptly passes into the blood capillaries.

It appears, therefore, that, though they travel along different routes, the dissolved amino acids, sugar and salts, on the one hand, and the emulsified fats, on the other, find their way from the intestinal canal to the right side of the heart. From there, as has been seen, the blood is driven to the lungs to be oxygenated, thence to the left side of the heart, and from there to all parts of the body save the lungs. Not much is known of the exact processes whereby the blood, out of the materials it derives from the alimentary canal, enables the

work of reparation or construction in all parts of the body—for example, the building up of bone in one place, the formation of muscular fibre in another, and the storage of fat in a third. We know, however, that repair and growth depend on the constructive activity of the living substance (protoplasm) of the body, and the materials for this work are the products of digestion.

But the student should now be in a position to grasp the fact that all parts of the animal body have at one time or another passed through, and formed part of, the blood, and, further, that the blood is the medium through which such materials as hay and corn and roots are manufactured into such products as beef and mutton, milk and wool.

Gains and Losses of the Blood.—To sum up with regard to the blood. It has been seen that the blood gains material (amino acids, carbohydrates, fats, salts, water) from the food in the alimentary canal; that it gains material (oxygen) from the air in the lungs; that it gains material (the products of activity and waste) from the tissues generally; and that it gains material (lymph) from the lymphatics. On the other hand, the blood loses material (carbon dioxide and water) at the lungs; it loses material (urea, hippuric acid, water, saline substances) at the kidneys; it loses material (water, saline substances) at the skin; and it loses material (used for constructive purposes) in the tissues generally.

Nervous System.—The various organs of the body are under the control of nerves, and it is through the nervous system that the movements of the body are co-ordinated, so that there shall be no conflict of purpose. The brain, with its posterior continuation—the spinal cord—constitutes the central part of the nervous system. The brain and spinal cord make up what is known as the "cerebro-spinal nervous axis," the whole of which is securely lodged and efficiently protected in the bony chamber formed by the skull and the vertebræ. Processes or outgrowths, given off in pairs from the axis, form the cerebral and spinal nerves. Some of the former are nerves of special sense, as the olfactory nerve (associated with the sense of smell), the optic nerve (associated with sight) and the auditory nerve (associated with hearing). A number of pairs of very important nerves arise from a region called the "medulla oblongata," at the junction of the brain and spinal cord. One of these, the "pneumogastric" nerve, or "vagus," distributes its fibres to the heart, the lungs, and the stomach.

All muscular contraction takes place in obedience to nervous influence. This is equally the case with the voluntary movements of the muscles of the limbs (as in running or walking), and with the involuntary movements of the intestinal canal (peristaltic contractions) and of the heart. The quantity of blood which shall flow to any part of the body is equally determined by the nervous system, inasmuch as the "vaso-motor" nerves control the calibre, or internal diameter, of the small arteries. Most important results arise from this circumstance.

The SENSE ORGANS of touch, taste, smell, hearing and sight are the means by which information about surroundings is obtained. A description of their structure and modes of action is outside the scope of this book.

Organs of Internal Secretion.—In addition to the various systems of organs above described, there are others that have developed to a special degree the power of altering the composition of the blood by secreting into it chemical substances which are conveyed in the circulation to other parts of the body, on which they exert a special influence promoting growth or glandular secretions, or some other functional activity. The suprarenal bodies, which are situated just in front of the kidneys, are an example of such organs. These internally secreting glands elaborate a substance of known chemical composition called "adrenalin," which acts on the muscles, particularly those of the heart and blood-vessels. If the suprarenals are removed extreme weakness, associated with muscular collapse, occurs, and is followed by death. The thyroid glands, situated in the neck, are another example. These produce a chemical substance known as "thyroxin," which is essential for normal growth. The pituitary gland, situated beneath the groin, is another organ which produces several internal secretions which control growth, reproductive activity, and other functions. Moreover, there are organs which, besides having other functions, are in addition glands of internal secretion. Thus, the pancreas controls the power of storage of carbohydrate by the liver, by means of a secretion known as "insulin," and if this substance is produced insufficiently diabetes results, sugar being excreted in the urine. Under normal conditions carbohydrate is stored in the liver in the form of glycogen, and is released into the blood in the form of sugar as required, so that in a sense the liver is an organ of internal secretion, the product secreted being grape-sugar or glucose. The reproductive glands—testes and ovaries, referred to below—are also organs of internal secretion.

Reproduction.—The essential male organs are the "testes" (or testicles), which in all farm animals, as in man, are a pair of glands lying outside the main body cavity in the "scrotum," a double sac placed between the anus and the penis or copulatory organ. The testes not only give rise to the male reproductive cells or "spermatozoa" but also elaborate chemical substances or internal secretions which pass into the blood, and by their power of stimulation are largely responsible for the growth of the distinctively male characters other than the actual possession of the testes. Castration, or the removal of the testes, has a general de-sexing effect (like ovariotomy in the female). It prevents the animals from experiencing sexual desire and favours fattening.

A fully formed spermatozoon consists of an egg-shaped head, a short cylindrical body and long vibratile tail, by which it swims in the fluid medium called the "semen" provided by the testes and accessory reproductive glands ("seminal vesicles," "prostate,"

"Cowper's glands," etc.). A single spermatozoon (say of a horse) is about 1/500th of an inch in length. A normal ejaculation of semen may contain several hundred million spermatozoa.

The spermatozoa pass from the testis on each side into a long central tube, the "epididymis," which serves as a storehouse for them until such time as they are ejaculated. When this occurs they pass, together with some of the fluid secreted, along two ducts or "vasa deferentia" contained within the inguinal canals on either side and running back into the body cavity. These ducts open close together into the common urogenital passage, with which the bladder also communicates. This passage, called the "urethra," into which the accessory glands also open, is continued within the erectile penis, at the end of which it communicates with the exterior.

The "ovaries" or essential reproductive organs in the female are a pair of glands situated in the body cavity attached to the dorsal wall. They not only produce the eggs or ova, but they also elaborate internal secretions responsible for the development of the female characters and for the periodic sexual changes which characterise the female reproductive or "œstrous" cycle. The ovum in a farm animal is similar to the yolk of a hen's egg in miniature, being only about 1/300th of an inch in diameter. In contrast with the spermatozoa of the male, these ova are produced in small numbers, in many animals such as the mare and the cow, only one being discharged at a time, but a larger number are released in the sow, the bitch, the rabbit, etc., in approximate relation to the size of the litter. The act of discharge, which is called "ovulation," occurs at the period of heat or œstrus, when sexual intercourse commonly occurs.

The discharged ova are taken up by the expanded internal ends of the "oviducts," which are somewhat coiled tubes, one on each side, widening out behind into the horns connected to the uterus or womb. The two horns come together to form the corpus uteri, which opens posteriorly into the broad urogenital passage known as the "vagina," the latter communicating with the exterior at the "vulva" or external female organ. The "clitoris" is a small rod-like erectile organ which projects into the vulval aperture.

The ovum is usually fertilized by the spermatozoon in the oviduct, the two cells uniting together. The fertilized ovum then passes down the oviduct into the uterus, where it undergoes development during the period of gestation, as the embryo or fœtus. It becomes secondarily attached to the inside of the uterus by the afterbirth or "placenta," which brings the blood system of the mother into close relation with that of the embryo, and acts as an organ of fœtal nutrition, respiration and excretion. In parturition, or the act of giving birth, the uterine muscles, which at this time are greatly hypertrophied, contract forcibly, and in association with the muscles of the body wall, expel the young through the vagina and out to the exterior.

The mammary glands, although not directly concerned with the

reproductive organs, are dependent upon the ovaries for their growth. They consist of milk-secreting tissue surrounded by a fibrous envelope, the whole constituting the udder in farm animals. The glands are connected with the nipples or teats, which communicate with the exterior and are sucked by the young animal.

Among farm animals, speaking generally, the male is capable of service all the year round. In the female, on the other hand, the times for service are restricted to the heat or œstrous periods, and these may occur only during a part of the year, as with many breeds of sheep. Ovulation occurs during or about the times of œstrus. In the bitch there is only one heat period to the breeding season; that is to say, a bitch, if not successfully served when on heat, does not "come on" again for a prolonged interval, typically about six months. On the other hand, the ewe, if not successfully served at her first period for the season, "comes back to the ram" (that is, comes on heat again), after an interval of about a fortnight, and this recurrent periodicity may continue for a number of times before service is accomplished or the ewe goes out of season. The mare, cow and sow are similar, except that the cycle with these animals is in each case about three weeks, and the breeding season may comprise the whole year.

Fertility among domestic animals depends upon a number of factors, some inherent in the animals themselves, and others depending upon environment and food supply. There can be no doubt that the inherent factors are hereditary, and the tendency to produce twins, for instance, among sheep can be transmitted, not only through the ewe, but also through the ram, so that rams which were twins can pass on the capacity of twin bearing to the next generation of ewe lambs. With regard to the state of nutrition of the animal, there is no question that a rising or improving condition before service is more favourable to fertility than a stationary or falling one. Moreover, very fat animals are notoriously uncertain breeders, and for this reason beasts fattened for show or sale are often temporarily sterile.

The essential principles governing the reproduction of birds are similar to those of mammals, but in a bird the ovum ("yolk" of the egg) is of large size, owing to the fact that it is crammed with nutriment to be used in building up the embryo. Before passing from the body of the mother a further supply of nutritive material ("white" of the egg) is added, and external to this a double membrane (shell membrane) and calcareous shell. Both the latter are pervious to air, for the developing embryo needs to breathe.

When hens' eggs are placed in "water glass" the pores in the shell are blocked up and breathing prevented. Such eggs "keep" because the development of their embryos is thus arrested.

For further information see :—

The Physiology of Farm Animals. F. H. A. Marshall and E. T. Halnan. 3rd. Edition. Cambridge, 1932.

Fertilising and Animal Breeding. Bulletin No. 2. Ministry of Agriculture and Fisheries: London, 1932.

CHAPTER XIX.

FOODS AND FEEDING.

The Constituents of Feeding Stuffs.—The chemist has shown that all feeding stuffs contain varying proportions of protein, oil, carbohydrate, minerals and water. If a typical fodder such as grass is heated strongly, the water is first driven off in the form of steam. The organic matter of the grass, composed of protein, oil and carbohydrate, then undergoes charring, and is subsequently burnt away completely in the form of carbon dioxide and water vapour. A small amount of greyish-white residue is left, which consists of the inorganic or mineral components of the grass. It is usually referred to as the ash, and is found to be rich in lime, phosphate and potash.

Plant Life in Relation to Animal Nutrition.—The plant is the elaborator of the food of animals. It alone, if we except the synthetic art of the chemist, has the power to bridge the gulf between the worlds of inorganic and organic matter. Starting from simple inorganic compounds like water, carbon dioxide and nitrates, the plant, under the influence of light absorbed by the chlorophyll pigment, is able to build up complex organic substances like protein, oil and carbohydrate. In these substances are locked up, in the chemical or potential form, the vast stores of energy which have been derived from the sun.

The work accomplished by the sun in this process is enormous. Every gramme of carbohydrate thus elaborated in the plant involves a storage of solar energy to the extent of 4,100 calories ; in other words, an amount of energy which, if liberated as heat, would suffice to raise the temperature of nearly a gallon of water through one degree centigrade. This locked-up energy becomes manifest as light and heat when the carbohydrate is burnt in an atmosphere of oxygen, which is the great liberator of imprisoned energy. In this process the carbon dioxide is set free once more and forms again the starting point in the eternal cycle of change. Oil is even a richer storehouse of energy than carbohydrate, and yields, when burnt in an atmosphere of oxygen, two and a third times the amount of heat as is obtained from an equal weight of carbohydrate. Protein under these conditions gives out rather less than one and a half times the amount.

A feeding stuff is therefore to be regarded as a mixture of organic compounds in which varying amounts of solar energy have been locked up. This energy is available, in part, to the animal, which is merely, in the scientific sense, a mechanism for the transforming of energy from one form to another. The principle of the conservation of energy holds as rigidly for the animal as for the clock or the engine. Part of the energy of the food is transformed into heat for keeping up body temperature. Another part is utilized for maintaining the blood circulation and the heart beat,

or for the performance of muscular work. Still another portion may become locked up in the various organic compounds which are built up in the animal, such as reserve fat, the glycogen of the liver, the proteins of flesh or the constituents of milk. Thus it is apparent that life is fundamentally a phenomenon of energy exchange, the plant in the first place collecting and storing the energy of the sun and then passing it on for transformation in the animal organism.

The Protein of Feeding Stuffs.—Protein, the flesh-forming constituent of feeding stuffs, is of primary importance from the standpoint of nutrition, since it is an indispensable component of the diets of all animals. The activities which go on in the cells of the animal body involve a continual destruction, or partial destruction, of the cell proteins. It is clear, therefore, that the "wear and tear" of the vital activities entails a continual wastage of body protein in the animal. For this reason, an animal must receive at least an amount of protein in its daily ration sufficient to make good such losses. The first call on food protein is for the purpose of repairing worn-out body tissue. Although, in the case of human beings, the magnitude of this minimum protein requirement has never been satisfactorily defined, it is known with a good degree of certainty for farm animals. The scientific feeding standards are based on the principle of supplying, in the first place, an allowance of food containing sufficient digestible protein and energy for maintenance purposes, and then adding to this a further allowance in conformation with the production requirements of the animal.

Like all other substances, proteins, such as casein and albumin in milk or gliadine in wheat, are made up of almost infinitely small particles known as molecules. Compared with the molecule of a substance like common salt, however, that of protein is big and complex. A molecule of protein is formed by the union of a very large number of molecules of much simpler construction. These simpler substances are called amino acids, and they may be regarded as the "building stones" from which the complex protein is built up. About twenty different amino acids have been isolated from proteins. They all contain the elements carbon, hydrogen, oxygen and nitrogen, and two at least contain the element sulphur as well.

The digestion in the animal of the protein of feeding stuffs results in its breakdown to the amino acids from which it was originally built up. Unlike protein, the amino acids are soluble, crystalline substances, capable of ready absorption from the intestinal tract into the blood stream. It is in the form of amino acids, therefore, that food protein ultimately passes into the blood stream. The simplification of the protein into its constituent amino acids is brought about by the successive actions of three digestive ferments, or enzymes, viz., pepsin in the stomach, trypsin in the duodenum and erepsin in the small intestine. The nature of the enzymatic digestion of protein will be appreciated when it is stated

that, in order to imitate such change in the laboratory, it is necessary to boil protein with fairly concentrated hydrochloric acid for about two days.

How do the amino acids function after their absorption into the blood stream? There is a first call on them for the repair of "worn-out" body tissue. This is referred to as the maintenance protein requirement of the animal, and represents the sole protein requirement of the mature, non-producing animal. In the growing animal, there is a further demand for amino acids for the building up of new flesh protein (live-weight increase). The dairy cow also requires an extra supply of amino acids for synthesising the proteins of the milk secretion. In the case of the fattening animal, however, it is necessary to feed only a small amount of digestible protein in excess of the maintenance requirements of the animal.

It is of interest to inquire what happens to the excess of amino acids when protein is fed to an animal beyond its requirements for maintenance and production. Such surplus amino acids are subjected to a change, known as de-amination, which is mainly brought about during the passage of the blood through the liver. As a result of this change, the amino acids are deprived of their nitrogen, which is removed in the form of ammonia. The latter is rendered innocuous to the organism by combination with carbon dioxide in the blood stream and is finally transformed into urea, which is excreted as a waste product through the kidneys into the urine. The nitrogen in protein fed in excess of the actual requirements of an animal is not retained in the body, but is lost in the urine in the form of urea.

By the removal of the nitrogen from the amino acids, however, the latter are converted into organic acids of the nature of lactic acid, the acid of sour milk. Should the carbohydrate in the ration be insufficient to supply the animal with ample energy, these organic acids may undergo oxidation in the body to provide the necessary warmth and energy. If there is no need in this direction, however, such organic acids are able to undergo complex transformations with the formation of fat in the body. An excess of digestible protein in the ration functions, therefore, in much the same way as does carbohydrate and can, according to circumstances, constitute a source of energy or of body fat.

Carbohydrates and Oils in Feeding Stuffs.—The carbohydrates of feeding stuffs include the sugars, such as glucose, fructose and cane sugar, and the polysaccharides, such as starch, cellulose, dextrins and pentosans. The digestion of starch is brought about by the successive actions of the enzymes ptyalin of the saliva, amylopsin of the pancreatic secretion and maltase in the small intestine. It results in the breakdown of the starch to glucose, in which form starch ultimately undergoes absorption into the blood stream. The digestion of cellulose and pentosans is not brought about by normal enzymatic activity, but is the result of the action of bacteria in those parts of the alimentary tract where the food stagnates.

Further reference will be made to the process of bacterial digestion of cellulose at a later stage.

The glucose resulting from the digestion of the more complex carbohydrates serves primarily as a source of energy for muscular activity. It is oxidised in the body to carbon dioxide and water. Any excess may be stored temporarily, mainly in the liver, in the form of glycogen, which carbohydrate reserve may be drawn on when the concentration of glucose in the blood falls below its normal level. It is now definitely established, however, that a surplus of carbohydrate in the diet beyond the energy requirements of the animal may be stored in the body in the form of fat. The fattening value of such carbohydrate-rich foods as maize and barley is well recognized by the pig-feeder. Kellner has demonstrated that the consumption of 4 lb. of digestible starch leads to the production of 1 lb. of fat in the body of a fattening bullock.

The oil of feeding stuffs is digested by the joint activity of the bile and pancreatic secretions. The bile emulsifies the oil of the food, thus facilitating its digestion by the fat-splitting enzyme, steapsin, which hydrolyses oils and fats to glycerol and fatty acids, such as palmitic, stearic and oleic acids. These breakdown products are absorbed from the intestine into the lymphatic system and, during their transfer, are re-synthesised into neutral fat.

Fat may be regarded as the main fuel of the body. Its oxidation in the animal to carbon dioxide and water gives rise to two and a third times as much heat as arises from the oxidation of an equal weight of carbohydrate. The production of fat in the animal is, therefore, an efficient method of storing up reserves of energy, and its presence confers the power of enduring starvation. Kellner has shown that 1 lb. of the digestible oil in oil cakes leads to the formation about 0·6 lb. of fat in the bodies of fattening cattle.

Minerals in Feeding Stuffs.—Recent research has emphasized the importance of paying attention to the amount and nature of the inorganic constituents of the rations of farm animals, since the mineral components of the animal body are as essential to the living processes as are the energy-furnishing organic constituents. Hydrochloric acid, for example, is essential to gastric digestion. The transport of oxygen in the blood is effected by haemoglobin, a complex compound of iron. Alkali is necessary for the actions of the ferments ptyalin, trypsin and amylopsin. Most important of all, lime and phosphate are required for the formation of bone and of milk. Directly or indirectly, the inorganic constituents stimulate and control all the vital bodily processes.

A correct diet must supply all the essential minerals. Moreover, the blood and tissues must receive them not only in correct amount, but also in correct proportions or balance. The kidneys have the power of eliminating those minerals which are present in excess, while those which may be deficient are conserved in the animal. The bones afford an example of the power of the organism of regulating the balance of the minerals. They are not to be regarded as

inert tissues, but as acting as a storehouse of lime and phosphate, the latter being drawn on when the blood contains a deficiency of these minerals, or, alternatively, if the blood contains lime and phosphate in excess of the normal amounts, these are deposited in the bones.

Just as a dairy cow requires a definite amount of digestible protein in its maintenance food for repair of " worn-out " tissue, so it must also be supplied with definite amounts of lime and phosphate to make good the losses of minerals which arise from wastage in the essential vital processes. A cow of average weight requires, for such purposes, 1½ oz. of lime and [illegible] oz. of phosphoric acid in its daily ration. In addition, it must receive a further supply of these constituents in conformation with its milk yield. A gallon of cow's milk contains ¼ oz. of lime, ⅓ oz. of phosphoric acid and ⅙ oz. of chlorine. Since only a half of the mineral supply of the food is assimilated by the animal, the dairy cow should receive, per gallon of milk and in addition to its maintenance supply, ½ oz. of lime, ⅔ oz. of phosphoric acid and ⅓ oz. of chlorine. Under such conditions, the animal will be able to maintain its milk yield without having to draw on its skeletal reserves for lime and phosphate.

One per cent. of the live-weight of a store pig consists of lime and rather less than this amount of phosphoric acid. In the case of cattle, lime represents 2 per cent. of the body weight, phosphoric acid again being present in slightly smaller amounts. On the basis of 100 lb. live-weight increase, therefore, the pig must build into its body 1 lb. of lime and 1 lb. of phosphoric acid, while the bullock must incorporate 2 lb. of each of these constituents. Since these animals are able to assimilate only half the minerals supplied in the food, twice these amounts must be supplied per 100 lb. of live-weight increase. A growing pig, increasing in live-weight at the rate of 1½ lb. per day, requires ½ oz. each of lime and phosphoric acid in its daily ration. A calf growing at the same rate must be supplied with twice these amounts.

The distribution of the minerals in some of the common feeding stuffs of the farm is shown in Table I.

TABLE I.—MINERAL CONTENT OF SOME TYPICAL FEEDING STUFFS.*

	Total Ash	Lime (CaO).	Phosphoric Acid (P_2O_5)	Chlorine (Cl.)	Iron Oxide (Fe_2O_3)
	per cent.	per cent.	per cent.	per cent.	per cent.
Oats	3·50	0·14	0·81	0·07	0·04
Maize	1·50	0·02	0·69	0·07	0·01
Wheat	1·90	0·06	0·86	0·08	0·02
Bran	6·30	0·09	2·95	0·09	0·03
Swedes	0·90	0·08	0·08	0·04	0·01
Mangolds	1·00	0·02	0·04	0·16	0·01
Lucerne hay	8·60	1·95	0·54	0·47	0·17
Red clover hay	7·10	1·60	0·39	0·24	0·07
Wheat straw	5·20	0·29	0·13	0·20	0·03
Young pasture grass (dry matter)	9·50	1·20 to 1·80	0·90 to 1·10	0·90	?
Cottonseed meal	6·20	0·36	2·67	0·04	0·80
Fish meal	21·00	10·00	9·00	0·50	Trace
Skim milk (dry matter) ...	7·96	1·87	2·24	0·95	0·07
Whey (dry matter)	7·28	1·01	1·46	0·95	0·04

* Abstracted mainly from the publications of the Rowett Institute, Aberdeen.

The cereals in general are poor in lime and chlorine, but rich in phosphoric acid and potash. Among this group, oats are the best balanced and richest in respect of minerals. Roots and tubers are deficient in minerals, especially in lime. The leguminous fodders, including lucerne, sainfoin, vetches and clovers, are rich sources of lime, while the cakes and meals, in general, are poor in lime and rich in phosphoric acid. Young, leafy pasturage is a satisfactory source of minerals and, next to milk, is the best balanced food on the farm in respect of inorganic constituents. The richness of white fish meal in respect of both lime and phosphate is especially noteworthy, and to this feature is partly to be attributed the good results which follow its inclusion in the rations of growing pigs.

In the feeding of many classes of stock, notably high-yielding dairy cows and animals designed for early maturity, it is desirable to include a mineral supplement in the ration. The following mixture is commonly used as a mineral supplement for dairy cows :

2 parts by weight of common salt.
1 part by weight of finely ground chalk.
1 part by weight of sterilized feeding bone flour.

3 lb. of this mixture should be mixed thoroughly with every 100 lb. of concentrated food. If salt is already supplied in the form of rock salt or salt licks, it should be omitted from the mixture. It is important, however, that dairy cows should be supplied with salt, since the concentrated foods generally are deficient in respect of this ingredient.

The following mineral supplement may be used for swine :

1 part by weight of sterilized feeding bone flour.
1 part by weight of precipitated finely ground chalk.
½ part by weight of common salt.

This mixture is used at the rate of 3 lb. to every 1 cwt. of meal. It may be mixed with the meal ration, or it may be placed in troughs, either mixed or in the form of the separate ingredients, and the pigs be allowed to adjust their consumption according to their individual requirements. In addition to the three ingredients mentioned, the supplement may with advantage contain about 10 per cent. of wood ashes and about 2 ounces of potassium iodide to every 100 lb. of mineral mixture. Recent research on pig-feeding has shown that the bone flour may be omitted from the above mineral supplement, since cereals, which constitute the basis of pig and poultry rations, are rich in phosphorus, although deficient in lime and chlorine. The supplement for pigs and growing chickens need only provide ground chalk (1½ per cent.) and common salt (½ per cent.). Scientific opinion it still divided on the question of iodine for stock, but it is becoming clear that the use of potassium iodide in farm rations is, in general, both unessential and uneconomic.

Vitamins in Feeding Stuffs.—Prior to the year 1912, it was thought that if a ration supplied protein, carbohydrate, fat and minerals in correct amounts and proportions, then, with the necessary water, everything was present which was essential to ensure

the well-being and proper nutrition of the animal. It has been necessary, however, to modify this view in the light of the results of recent biological enquiry. It is now recognised that natural foods contain minute amounts of some substances, termed accessory food factors or vitamins, which make an essential contribution to growth and health in animals. Five such substances, known as vitamins A, B, C, D and E, are now known to exist in feeding stuffs and plant products.

Vitamin A.—The most important sources of this vitamin are milk, butter, egg yolk, cod liver oil and sheep liver oil. It is important to emphasise, however, that the primary source is the green plant, and that if it is not contained in the diet of the dairy cow, therefore, it will also be absent from the milk of the animal. Lack of this vitamin in the diet leads to retardation of growth in young animals, and in the case of adult animals, appears to lower the resistance to infectious disease. The results of recent vitamin research have shown that carotene, the yellow pigment of plants, is the precursor of vitamin A.

Vitamin B.—Continuous deficiency of this vitamin in the diet of animals leads to acute nervous disorders. It is present in important amount in milk, yeast, rice bran, wheat bran and wheat germ.

Vitamin C.—In the absence of supplies of this vitamin, animals develop the condition known as scurvy. Guinea-pigs, in particular, are susceptible to scurvy and develop the disease if kept for about three weeks on an oat and bran diet. The condition can be cured by administering small amounts of fresh fruit and vegetables. Vitamin C is also present in roots and fresh green plants.

Vitamin D.—In association with vitamin A, the vitamin D occurs in cream and cod liver oil. It is essential to the normal development of bones and teeth. Vitamin D can be produced from a substance called ergosterol by the action of sunlight or ultra-violet light. Small doses of such "irradiated ergosterol" are useful for curing rickets in the early stages. Ergosterol is present in the skin of animals. By exposing the skin to sunlight, the ergosterol is transformed into vitamin D for use in the organism. Vitamin D formed in this way in the skin of the dairy cow finds its way into the milk secretion. Such findings as this emphasise the importance of light and airy surroundings in maintaining good condition in farm animals.

Vitamin E.—This vitamin, which has been shown to be present in wheat germ oil, red meat and green plants, appears to be essential to fertility in animals. Experiments on rats have demonstrated that the prolonged absence of this vitamin from the diet leads to sterility in such animals.

The distribution of vitamins A, B and C in some of the common feeding stuffs of the farm is shown in Table II. It may be assumed that feeding stuffs which are rich in vitamin A also contain vitamin D.

TABLE II.—VITAMINS IN FARM FEEDING STUFFS.

	Vitamin A.	Vitamin B.	Vitamin C.
Young pasture grass ...	Plentiful amount	Plentiful amount	Plentiful amount
Fresh lucerne	,, ,,	,, ,,	,, ,,
Fresh clover	,, ,,	,, ,,	,, ,,
Meadow hay	Moderate amount	Moderate amount	Trace
Tower silage	Plentiful amount	Plentiful amount	Small amount
Straw	None	None	None
Roots	Small amount	Small amount	Plentiful amount
Bran and middlings ...	,, ,,	Plentiful amount	None
Barley meal	,, ,,	Moderate amount	,,
Linseed cake	Moderate amount	Plentiful amount	,,
Cottonseed cake	,, ,,	,, ,,	,,
Coco-nut cake	Trace	Moderate amount	,,
Ground nut cake	None	,, ,,	,,
Dried yeast	(?)	Plentiful amount	(?)
White fish meal	Moderate amount	(?)	(?)

It cannot be said that the discovery of vitamins has led to any outstanding modification in the previously accepted principles of farm feeding. It appears that farm animals are not so prone to the diseases associated with vitamin deficiency, as are rats and guinea-pigs, on which animals the early discoveries in connection with vitamins were made. The home-produced feeding stuffs, including grain, grain offals, grass, hay, roots, silage and dairy by-products, are excellent sources of vitamins, and it would be a matter of difficulty to devise a ration containing such feeding stuffs which would lead to diseases of malnutrition in farm animals, such as could fairly be ascribed to lack of vitamins. Nevertheless, it has been shown that small doses of cod liver oil, containing vitamins A and D, improve the general condition and rate of growth of sty-fed pigs, and that the vitamin content of winter milk may be improved by administering small amounts to dairy cows. On account of the risk of tainting, however, it is necessary to be cautious when using cod liver oil for such purposes. Moreover, excessive administration of cod liver oil to dairy cows results in a distinct lowering of the percentage of butter fat in the milk. The vitamin D content of winter rations may be enhanced by the inclusion of small amounts of such substances as "irradiated yeast" or "irradiated ergosterol."

Analysis of Feeding Stuffs.[1]—The composition of a feeding stuff is arrived at by determining its percentage content of moisture, ash, protein, oil, fibre and carbohydrate. The percentage of moisture is estimated by determining the loss in weight which occurs when a weighed quantity of the food is dried to constant weight in a steam oven. The dried residue is then ignited strongly to burn away the organic matter, and the percentage of ash is calculated from the weight of residue left behind.

The crude protein (i.e., total protein) in the feeding stuff is found indirectly by estimating its nitrogen content according to the technique of the Kjeldahl method. For this purpose, 1 to 2 gm. of the food is digested for some hours with 20 c.c. of concentrated sulphuric acid, to which is added about 10 gm. of potassium sulphate and a crystal of copper sulphate. During this process, the whole

of the nitrogen in the food is transformed into ammonia and exists as ammonium sulphate in the clear residual liquid remaining after the completion of the digestion. The amount of nitrogen is then ascertained by washing the residual liquid into a distilling flask, adding strong sodium hydroxide solution to make the contents alkaline and distilling off the ammonia into a measured volume of standard hydrochloric acid. The nitrogen is converted into protein by multiplying by the factor 6·25, on the assumption that proteins contain about 16 per cent. of nitrogen.

It should be pointed out, however, that a part of the nitrogen of feeding stuffs is not present in the form of true protein, but as simple nitrogenous substances like amino acids, ammonium salts and amides. These simple nitrogenous materials are usually grouped together under the name of "amides" and their amount is considerable in roots, tubers and silage. Special analytical methods have been designed for the determination of the percentages of true protein and "amides" in feeding stuffs.

The oil content of feeding stuffs is determined by extracting a weighed amount with ether in a Soxhlet apparatus. This fraction, therefore, includes all the ether-soluble constituents of the food and is technically referred to as the "ether extract." To determine the percentage of crude fibre, a weighed amount of the food is boiled for thirty minutes with 200 c.c. of 1¼ per cent. sulphuric acid. The residue from the acid treatment is then boiled for thirty minutes with 200 c.c. of 1¼ per cent. potassium hydroxide solution, and the residue, which consists of fibre admixed with sand, is dried and ignited. The loss of weight on ignition represents the crude fibre.

The percentage of carbohydrates, often referred to as the nitrogen-free extractives, is not determined by direct experiment, but by subtracting the sum of the percentages of moisture, ash, protein, oil and fibre from 100.

The Digestibility of Feeding Stuffs.—The crude composition of a feeding stuff, as determined by the methods just outlined, does not give a safe indication of feeding value, since only that portion of the food which the animal is able to digest and assimilate can contribute to maintenance and production. It is necessary, therefore, to secure information about the extent to which the common feeding stuffs are digested and utilized by farm animals. This is done by carrying out digestion trials, with wether sheep, bullocks or pigs, according to the following plan:

The experimental animal, most frequently a wether sheep, is fitted with a light harness and placed in a metabolism crate, the object of crate and harness being to enable the urine and fæces of the animal to be collected separately. During an initial period of seven days, the animal is given a weighed ration of the food under investigation, at the end of which time, it can be assumed that the dung of the animal is composed of undigested residues from the experimental ration. During the next fourteen days, the

liquid and solid excreta are collected separately and their amounts measured. The mean daily output of fæces is thus ascertained. Representative samples of the food and fæces are next submitted to analysis, and from the data thus obtained, it is possible to calculate the weights of protein, oil, fibre and carbohydrate which the animal is consuming daily and the mean weights of these constituents which are being voided in the dung per day. The amounts digested by the sheep are then calculated by difference. For example, if 80 gm. of protein are consumed in the daily ration and 30 gm. are voided, on an average, in the dung, the percentage digestibility, or digestion coefficient, of the protein of the food is $(80-30) \times \frac{100}{80} = 62{\cdot}5$ per cent. The digestion coefficients of the remaining constituents of the food are calculated in a similar manner, and by combining these values with the percentages of crude nutrients, the amounts of digestible nutrients in the feeding stuff are obtained. Thus, linseed cake contains 29·5 per cent. of crude protein. By digestion trials on sheep, however, it has been found that only 85·8 per cent. of the linseed cake protein can be digested and utilized in the bodies of farm animals, the remaining 14·2 per cent. being voided in the fæces. The percentage of digestible protein in linseed cake is, therefore, $29{\cdot}5 \times \frac{85{\cdot}8}{100} = 25{\cdot}3$ per cent.

The data respecting the digestible composition of a feeding stuff give a much more reliable indication of feeding value than can be obtained by a consideration of the results of chemical analysis alone. From such figures can be calculated the nutritive value of a feeding stuff in terms of starch equivalent, and since the food requirements of farm animals are usually expressed in terms of digestible protein and starch equivalent, it will be necessary at this point to explain the significance of this new term.

The Starch Equivalents of Feeding Stuffs.—The method of assessing the nutritive values of feeding stuffs in terms of starch equivalents was worked out by Kellner, the German authority on the science of animal nutrition. It will not be possible to give more than a brief description of the experimental technique involved in Kellner's measurements. A bullock in store condition was placed in a respiration chamber and was fed on a ration composed of fodders such as meadow hay, clover hay and oat straw. The size of the ration was adjusted as nearly as possible to the maintenance requirements of the animal, under which conditions of feeding, the animal was neither gaining nor losing body fat and flesh. In a further period of feeding, the ration was increased by the addition of a definite weight of starch of known digestibility, and by means of measurements made possible by certain devices associated with the construction of the respiration chamber, the experimenter was able to find out how much fat was produced in the body of the bullock. Careful experiments showed that every 4 lb. of digestible starch eaten, over and above the maintenance ration, produced 1 lb. of fat in the animal's body.

Another period of feeding followed, in which the starch was replaced by a definite weight of linseed cake, and the amount of fat formed in the body of the animal was again determined. It was found that 4 lb. of linseed cake produced only about ¾ lb. of fat. This included the small amount of protein, stored as flesh, converted into its isodynamic weight of fat by multiplying the factor 5·7/9·5 (i.e., the ratio of the heats of combustion of body protein and fat). The fat-producing value of linseed cake, therefore, is only about three-quarters that of digestible starch, and for purposes of fattening, it is clear that 100 lb. of linseed cake is equal to about 75 lb., or, to be more precise, 74 lb. of digestible starch. The starch equivalent of linseed cake, therefore, is 74. By this is implied that 100 lb. of linseed cake, when consumed by a fattening steer in conjunction with its maintenance food, will produce as much fat in the body as would be formed by 74 lb. of digestible starch.

It was possible in this way to determine the starch equivalents of all the common feeding stuffs and thus to obtain a simple numerical comparison of their productive values. If, then, the food requirements of farm animals are defined in terms of starch equivalent and digestible protein, and the starch equivalent and digestible protein contents of the feeding stuffs are known, it is merely a matter of simple arithmetic to compute rations which shall contain the correct amounts of starch equivalent and digestible protein for any purpose which the stock-feeder may have in view. Examples of this kind of computation will be given later in this chapter.

Kellner also devised a second method whereby the starch equivalent of a feeding stuff may be calculated on the basis of its digestible composition. For this purpose, he determined the fat-producing values of the pure digestible constituents of feeding stuffs, such as digestible oil, digestible protein, digestible fibre and so on. He found that 1 lb. of digestible protein was equivalent to 0·94 lb. of digestible starch for fattening, and that 1 lb. of digestible oil had a starch equivalent of 2·41, 2·12 or 1·91, according as to whether the oil was derived from (1) oil cakes ; (2) cereals and leguminous grains, and their by-products, and (3) coarse fodders and roots. Digestible fibre and digestible starch were found to be equal from the standpoint of fat production in the bodies of fattening cattle, a finding which has led to the hypothesis that the bacterial digestion of 1 lb. of digestible cellulose in the paunch of ruminant animals, such as sheep, bullocks and dairy cows, gives rise to the formation of as much glucose sugar as is produced by the normal enzymatic digestion of 1 lb. of digestible starch.

To calculate the starch equivalent of a feeding stuff from its content of digestible nutrients, the following expression should be employed :

$$\text{S.E. per 100 lb.} = \left\{ (\%\ \text{dig. protein} \times 0{\cdot}94) + \left(\%\ \text{dig. oil} \times \begin{matrix} 2{\cdot}4 \\ 2{\cdot}1 \text{ or} \\ 1{\cdot}9 \end{matrix} \right) + \%\ \text{dig. fibre} + \%\ \text{dig. carbohydrate} \right\} \times V$$

The factor to be used for converting digestible oil into its equivalent of starch depends on the type of food under consideration (see above). It will be noted that it is necessary to introduce a correction factor V, known as the percentage availability of the feeding stuff, into the expression. The reason for this is as follows: If the calculated starch equivalent of a feeding stuff be checked against the value obtained by direct experiment on a bullock in a respiration chamber, the latter value is always lower than that predicted by calculation. In the case of linseed cake, for example, the experimentally determined value is 97 per cent. of the calculated value, V for linseed cake, therefore, being 0·97. This discrepancy arises from the fact that Kellner used the pure, finely-divided nutrients when he determined the starch equivalents of the digestible constituents. In actual practice, however, the digestible nutrients are never fed in this condition; they are embedded in the indigestible matter of the food. The animal finds it necessary to expend energy in masticating the indigestible portion, in separating it from the digestible part and in passing it along the alimentary tract for excretion. This expenditure of energy, though only small for foods of a highly digestible character, may be very large in the case of a feeding stuff containing a high percentage of indigestible fibre. The result of the using up of energy in dealing with the indigestible part of the food is to reduce, in a greater or smaller degree, the amount of energy which the animal should otherwise be able to derive from the digestible nutrients.

The V values are usually given in tables showing the composition and nutritive values of the feeding stuffs ([2]). For the concentrated feeding stuffs, V usually lies between 90 and 100 per cent. With the coarse fodders, where, on account of the high percentages of crude fibre, the correction is usually very large, it is customary not to employ the V factor, but to subtract, instead, the percentage of total fibre multiplied by 0·58, since Kellner has shown that every pound of fibre in the fodder causes the starch equivalent to be 0·58 lb. less than that calculated on the basis of digestible composition. If the fodder is chaffed before use, the deduction should be only 0·29 lb. of starch equivalent for every per cent. of crude fibre, since chaffing diminishes the energy required for mastication and digestion. It should be pointed out that, in recent years, it has been found necessary to increase the starch equivalents of the coarse fodders by one-fifth, in order to bring them into line with measurements of net energy made by Armsby in America.

Nutritive Ratio.—The nutritive ratio of a feeding stuff or ration is calculated by means of the following expression:

$$\text{Nutritive ratio} = \frac{(\%\ \text{dig. oil} \times 2{\cdot}3) + \%\ \text{dig. carbohydrate} + \%\ \text{dig. fibre.}}{\%\ \text{dig. protein}}$$

The numerator is a measure of the carbohydrate equivalent of the digestible non-protein constituents. To bring digestible oil to the basis of carbohydrate, it is necessary to multiply by 2·3, since 1 lb. of oil gives out, when completely burnt, 2·3 times as much

heat as is obtained by the complete combustion of 1 lb. of carbohydrate. The value of the nutritive ratio gives information about the balance of a feeding stuff or ration, and tells how many parts of "fuel" material, namely, digestible non-protein constituents expressed in terms of carbohydrate, are associated with 1 lb. of "flesh-forming" substance, namely, digestible protein.

The nutritive ratios of decorticated cottonseed meal, linseed cake, skim milk and whole milk are 1, 2·1, 2 and 4·2 respectively. Such values are termed "narrow" ratios and imply that the foods in question are rich in digestible protein. Seeds hay and meadow hay of very good quality have nutritive ratios of 6 and 5 respectively; values of this magnitude are termed "medium" ratios. Carbohydrate-rich foods are characterised by "wide" nutritive ratios, the values for barley and potatoes, for example, being 10 and 16 respectively.

Since the nutritive ratio defines the balance of a food or ration, the suitability of a given diet for any specific purpose may be checked by calculating its nutritive ratio. It must be confessed, however, that since it is now customary to define requirements in terms of starch equivalent and digestible protein, the conception of the nutritive ratio has become almost superfluous in connection with the computation of rations. A ration should be designed to supply the correct amount of starch equivalent, including a definite quantity of digestible protein, for the purpose in view, in which case, the balance of the ration automatically works out correctly.

The Manurial Values of Feeding Stuffs.—The consumption by farm animals of purchased feeding stuffs makes an essential contribution to the upkeep of fertility on the farm, since a fraction of the nitrogen, phosphoric acid and potash in the food finds its way into the excreta of the animals and becomes incorporated, during winter feeding, in the farm-yard manure, or, with grazing animals and folded sheep, is directly added to the land. The recommendations of the Committee on Residual Values of Fertilizers and Feeding Stuffs (1927) should be adopted when assessing the manurial values of feeding stuffs. Two-fifths of the nitrogen of the food should be allowed to the manure, and three-quarters each of the phosphoric acid and potash. The manurial values should be diminished by one-quarter when the feeding stuffs are fed to dairy cows.

The procedure for calculating manurial values may be illustrated by considering the case of linseed cake, which contains 4·7 per cent. of nitrogen, 1·7 per cent. of phosphoric acid and 1·3 per cent. of potash. The unit values of nitrogen, phosphoric acid and potash, in October, 1929, were 8s. 3d., 3s. 7d. and 3s. 1d. respectively. The current values, which, of course, depend on the market prices of fertilizers, may be obtained from the monthly tables published in the *Journal of the Ministry of Agriculture*. The calculation for linseed cake is carried out as follows:

		£	s.	d.
Value of nitrogen in manure	= ($4·7 \times \frac{2}{5} \times$ 8s. 3d.) ... ... =	0	15	6
,, P_2O_5 ,, ,,	= ($1·7 \times \frac{3}{4} \times$ 3s. 7d.) ... ... =	0	4	7
,, K_2O ,, ,,	= ($1·3 \times \frac{3}{4} \times$ 3s. 1d.) ... ... =	0	3	0
	l cake ... ... =	£1	3	1

Relative Prices of Feeding Stuffs.—That the prices per ton of the feeding stuffs do not afford a safe criterion of relative cheapness or dearness is apparent from a consideration of the following case : In January, 1930, the prices per ton of palm kernel cake and undecorticated cottonseed cake were £9 10s. and £7 2s. respectively. It might be concluded from these figures that palm kernel cake was the dearer food, but this is not the case.

The food value per ton of palm kernel cake is obtained by subtracting the manurial value per ton from the price per ton. It is, therefore, £9 10s. − 17s. = £8 13s. The starch equivalent of palm kernel cake is 75, that is to say, 100 lb. of the oil cake contain 75 lb. of starch equivalent. The starch equivalent contained in one ton is 75 × 22·4 lb. It is clear, then, that palm kernel cake supplies starch equivalent at a cost of £8 13s. ÷ (75 × 22·4) = 1·25d. per lb.

The starch equivalent of undecorticated cottonseed cake is 42 and its manurial value is £1 7s. per ton. The price of 1 lb. of starch equivalent in the form of undecorticated cottonseed cake is, therefore (£7 2s.—£1 7s.) ÷ (42 × 22·4) = 1·47d. It will be seen that palm kernel cake, although dearer on the basis of price per ton, is actually a cheaper food than undecorticated cottonseed cake, the criterion of dearness or cheapness of feeding stuffs being the prices at which they supply the unit amount of feeding value, namely, 1 lb. of starch equivalent.

Examples, illustrating this method of coming to a decision respecting the dearness or cheapness of feeding stuffs, are given in Table III. It should be pointed out, however, that the calculations are based on the prices per ton ruling in January, 1930, and that trustworthy conclusions can be made only on the basis of current prices. The farmer may save himself a great deal of trouble by consulting the tables of relative prices of feeding stuffs which are published every month in the *Journal of the Ministry of Agriculture*.

TABLE III.—RELATIVE PRICES OF FEEDING STUFFS. (*January*, 1930.)

Feeding stuff.	Starch equivalent per 100 lb.	Price per ton.	Manurial value per ton.	Food value per ton.	Price per lb. of Starch equivalent.
		£ s.	£ s.	£ s.	d.
Linseed cake	74	13 0	1 8	11 12	1·70
Undec. ground nut cake ...	57	9 10	1 6	8 4	1·56
Dec. ground nut cake ...	73	12 0	2 0	10 0	1·47
Soya bean cake	69	11 5	1 19	9 6	1·47
Undec. cottonseed cake ...	42	7 2	1 7	5 15	1·47
Wheat	72	9 17	0 12	9 5	1·38
Bran	42	6 10	1 1	5 9	1·38
Coco-nut cake	79	10 15	1 4	9 11	1·29
Palm kernel cake	75	9 10	0 17	8 13	1·25
Extracted palm kernel meal	71	8 15	0 17	7 18	1·20
Maize meal	81	9 5	0 9	8 16	1·16
Barley	71	7 10	0 9	7 1	1·07
Middlings	58	6 12	0 17	5 15	1·07
Dried sugar beet pulp ...	65	5 0	0 7	4 13	0·77

The Feeding Stuffs.—It is convenient to divide the feeding stuffs of the farm into the following groups :

(1) The roughages or coarse fodders, so termed on account of their bulkiness and their high content of crude fibre. In this class are included the various kinds of hay and straw, chaff, cavings, etc.

(2) The green fodders, including pasture grass, lucerne, vetches, kale, rape, mustard, oats and vetches, green maize, sugar beet tops, silage, etc.

(3) The succulent fodders, such as roots and tubers, characterised by their high moisture content and low content of fibre.

(4) The concentrated foods, including leguminous grains, cereal grains and their by-products, oil cakes, etc. In contrast to the roughages, the special feature of the concentrates consists in their supplying high feeding value in small bulk.

(5) Miscellaneous feeding stuffs, in which group are included a number of concentrates, such as fish meal, dried blood, meat meal, dried yeast, etc., which arise as by-products of industries connected with the preparation of foods for human consumption.

The Roughages or Coarse Fodders.—The composition and feeding value of a number of typical coarse fodders are shown in Table IV. For data concerning the analysis and nutritive value of the comprehensive list of feeding stuffs, the reader should consult " Rations for Live Stock." (*See* footnote [2] on p. 497).

TABLE IV.—COMPOSITION AND NUTRITIVE VALUE OF SOME TYPICAL COARSE FODDERS.

	Moisture %	Crude protein %	Oil %	Carbohydrate %	Fibre %	Ash %	Digestible protein %	Starch equivalent %
Barley straw ...	14·0	3·3	1·8	42·4	33·9	4·6	0·8	23·0
Bean straw	14·0	4·5	0·8	33·0	43·1	4·6	2·2	23·0
Oat straw	14·0	2·9	1·9	42·4	33·9	4·9	1·0	20·0
Wheat straw ...	14·0	2·9	1·3	39·8	35·9	6·1	0·1	13·0
Wheat cavings ...	14·0	8·6	1·1	42·7	22·7	10·9	—	—
Red clover hay (good)	16·5	13·5	2·9	37·1	24·0	6·0	8·5	38·0
Lucerne hay... ...	16·5	14·2	2·6	29·2	29·5	8·0	9·7	29·0
Meadow hay (good)	14·3	9·7	2·5	41·0	26·3	6·2	5·4	37·0
Meadow hay (very g'd	16·0	13·5	3·0	40·5	19·3	7·7	9·2	48·0
Seeds hay (ryegrass and clover) ...	14·0	12.0	2·8	37·4	27·5	6·3	6·2	29·0

An inspection of the figures in Table IV. shows that the chief characteristics of the coarse fodders are their high fibre content and their low content of oil. The straw of the cereals forms a bulky food, containing a very high percentage of indigestible fibre and only small amounts of protein and oil. Although it contains a moderate percentage of ash, the latter is of little value to the animal, since it consists very largely of useless silica and only to a small extent of compounds of lime and phosphoric acid. The nutritive value of straw is mainly dependent on the degree of ripeness of the crop at harvest time. The riper the crop, the poorer is the food value of the straw, since ripening is essentially a process of transference of food nutrients from stem to grain.

It is this circumstance which accounts for the fact that oat straw has the highest feeding value of the cereal straws, since it is customary, especially in Scotland and the north of England, to harvest oats before they are dead ripe. In Table IV., however, barley straw is shown to have a somewhat higher starch equivalent than oat straw. This slight superiority is due to the inclusion in the barley straw of the leaves and stems of grasses and clovers which have been sown with the barley. Wheat straw is more commonly employed as litter than for feeding to animals. When used for feeding, it is better not to chaff it, but to give it in the long condition, so that the animals may pick it over and select the more nutritious and palatable portions.

Chaff and cavings are separated in the thrashing process. The cavings contain most of the breakable leaves included in the crop and may, if rich in clover, have a fairly good feeding value. The chaff is usually soaked with pulped roots before use.

The most important of the roughages is meadow hay, a fodder which is exceedingly variable in respect of composition and feeding value. The protein content may be as high as 13 per cent. in meadow hay of good quality and as low as 7 per cent. when the quality is poor. The fibre content may vary at the same time from 20 to about 33 per cent. This difference in chemical composition is reflected in the amount of meadow hay required for the maintenance of a dairy cow, the amount varying from 14 lb. to 20 lb. per head per day, according to quality.

Three factors are mainly responsible for this wide variation in quality : (1) Botanical composition of herbage. The presence of clover in the herbage enriches the hay in protein and lime. It may be stated, in general, that the greater the content of clover, the higher the nutritive value of the hay. (2) Date of cutting—this is perhaps the most important factor determining the nutritive value of meadow hay. Early-cut hay has a higher feeding value and protein content than hay cut at a later stage of growth. (3) Weather conditions at time of cutting.—If the weather is wet and unsettled at the time of hay-making, the hay is liable to be of inferior quality, both from the standpoint of palatability and that of chemical composition. Rain leaches out a portion of the soluble nutrients from the herbage, this effect being most marked when bad weather sets in just before the fodder is ready for carting.

Seeds hay, made from a mixture of clover and grasses grown on arable land, is usually richer in protein and lime than meadow hay. Hay is also made from a variety of leguminous forage crops, such as lucerne, clovers and vetches. Reference to the composition and feeding value of these different kinds of hay will be made in the section dealing with green fodders.

The Green Fodders.—The composition and nutritive value of some of the common green crops grown for feeding to farm animals are given in Table V.

TABLE V.—COMPOSITION AND NUTRITIVE VALUE OF SOME COMMON GREEN FODDERS.

	Moisture %	Crude protein %	Oil %	Carbohydrate %	Fibre %	Ash %	Digestible protein %	Starch equivalent %
Pasture grass, close-grazing—								
Non-rotational ...	80·0	5·3	1·1	8·9	2·6	2·1	4·5	14·7
Rotational, with 3-weekly intervals	80·0	4·5	1·3	9·3	3·1	1·8	3·7	14·6
Pasture grass, extensive grazing; Spring value ...	80·0	3·5	0·8	9·7	4·0	2·0	2·5	11·2
Sugar beet tops	83·8	2·0	0·5	8·7	1·6	3·4	1·4	8·6
Cabbage, drumhead	89·0	1·5	0·4	5·9	2·0	1·2	1·1	6·6
Marrow stem kale ...	85·7	2·4	0·2	6·4	3·8	1·5	1·8	8·9
Thousand-headed kale	85·2	2·5	0·3	8·7	1·7	1·6	1·8	8·8
Mustard ...	85·1	2·9	0·4	7·3	2·9	1·4	1·9	7·2
Rape	85·9	2·8	0·8	5·7	3·5	1·3	2·0	6·9
Green maize	80·6	1·7	0·5	10·4	5·6	1·2	1·0	9·1
Crimson clover	81·5	2·8	0·7	6·9	6·2	1·9	2·1	8·9
Lucerne ...	76·0	4·5	0·8	9·6	6·8	2·3	3·2	9·1
Sainfoin ...	80·0	3·5	0·6	7·8	6·9	1·2	2·3	7·6
Vetch and oat silage ("green fruity") ...	72·7	3·4	1·2	12·5	8·0	2·2	2·2	12·8
Vetch and oat silage ("acid brown") ...	65·4	5·6	1·5	12·9	11·4	3·2	3·8	13·0

Recent research has shown that the food material in grass kept young and leafy by close grazing is not in any sense related in nutritive properties to a coarse fodder like hay, but has the protein-rich and highly digestible character associated with concentrated foods such as bean meal and linseed cake. The dry substance in young, leafy pasturage is, in other words, a protein concentrate of high digestibility and feeding value. By drying down young grass artificially and pressing it into nuts or cakes, a food is obtained which may be used as a substitute for oil cakes in the winter feeding of dairy cows and fattening bullocks. Besides supplying an abundance of highly digestible protein, such dried grass cakes are rich in bone and milk-forming minerals like lime, potash and phosphate. It has further been established that when a pasture is closely grazed at regular intervals, the high feeding value of the grass is independent of the type of herbage, or the presence of much or little wild white clover. Under such conditions, there is no running off in feeding value, provided rainfall is adequate to maintain active growth, during July and August, such as occurs on poorly-managed pasture, where the grasses are allowed to grow fibrous and stemmy. It is advisable that the mowing machine should occasionally be resorted to, when it is found impossible, by grazing alone, to keep the herbage young and leafy. The best results, from the standpoint of yield of nutrient food per acre per season, are obtained by dividing the extensive pasture into a number of smaller enclosures, the latter being grazed closely in succession. Every enclosure, therefore, is permitted an interval of unchecked growth between successive close grazings. Investigations at Cambridge have demonstrated that this interval may be at least of three to four weeks' duration without the herbage losing its " concentrate " character.

The green forage crops are of particular importance to the stock-feeder, since they provide an abundance of green succulent food for farm animals during periods of severe summer drought, when the pastures are apt to present a bare and scorched appearance. Among such crops may be mentioned lucerne, crimson clover, red clover, alsike clover, sainfoin and vetches, alone or in admixture with rye, bean or peas. These leguminous crops are characterized by their richness in lime and protein. It should be kept in mind that they fall off rapidly in respect of digestibility and nutritive value after arriving at full flower, and it is advisable, therefore, that they should be consumed in the stage of early flowering. They may be utilized for feeding in the fresh, green condition or, alternatively, they may be grown for conversion into hay for winter keep.

Lucerne, in view of its drought-resisting and high-yielding characteristics, is especially useful for helping out the pastures during a dry summer. When thoroughly established, it may give as many as four cuts in a season, the total yield of green fodder amounting to 15 to 20 tons per acre. When not required for feeding in the green condition during the summer, it may be grown for hay for use in winter. The yield of roughage amounts to 3 to 4 tons per acre. Lucerne hay has a high feeding value and is particularly rich in protein and lime, 1 lb. of this leguminous forage containing about 1½ ozs. of digestible protein and nearly ⅓ oz. of lime.

Green maize is a favourite fodder for dairy cows during the late summer and early autumn, when the productivity of the pastures is beginning to run off. It should be cut during the flowering period, when it contains between 16 and 18 per cent. of dry matter. Green maize is much poorer in protein than the leguminous forage crops. When used for dairy cows, therefore, it should be supplemented by food rich in protein, such as lucerne or oil cakes.

The sugar beet tops, which remain behind on the field when the sugar beets have been sent to the factory, form a useful food for sheep, ewes, dairy cows and bullocks during November, December and January. By the term sugar beet tops is meant the sugar beet leaves to which are attached the hard crowns of the roots. They contain from 83 to 85 per cent. of water, and the sugar of the crowns may constitute anything from one-tenth to one-fifth of the total dry matter in the tops. They are very highly digested by sheep and cattle, and, as a basis of feeding, 25 lb. of sugar beet tops may be regarded as being able to replace 40 lb. of mangolds. A maintenance ration of 14 lb. of hay plus 40 lb. of mangolds, for example, could be replaced by the same amount of hay plus 25 lb. of sugar beet tops. Since sugar beet leaves may contain significant amounts of oxalic acid and oxalates, it is advisable to allow the tops to wilt for about a week before usage. The process of wilting leads to a very material reduction in the oxalic acid content of the leaves. All risk of trouble from oxalic acid may be obviated by feeding chalk along with the tops, a suitable allowance being ¼ lb. of chalk per 300 lb. of sugar beet tops.

Cabbages are commonly grown for feeding to dairy cows in the late autumn, at a time when pasturage is scant and coarse. They are a watery, bulky food, containing, on an average, about 2 per cent. of protein. They are especially valuable because of their ability to withstand cold and frost, and, for that reason, are available for the purpose of maintaining the milk yield of dairy cows at a difficult time of the year. Dairy cows may receive up to 60 lb. per head per day.

Other green forage crops which are available for use in autumn and early winter are rape, mustard and marrow stem kale. Rape and mustard are grown more particularly for sheep-feeding, whilst marrow stem kale, besides being relished by sheep, is a favourite green food for dairy cows up to Christmas, after which time it is usual to go on to swedes and mangolds. Thousand headed kale, on account of its winter-hardiness, may be grown for use as a food for ewes and dairy cows in late winter and early spring.

Green crops are frequently preserved for winter usage in tower silos, clamps and stacks. The changes which modify the character of the green fodder during its conversion into silage are threefold : (1) The respiration of the living plant cells, which leads to a portion of the carbohydrate of the crop being oxidized to carbon dioxide and water. This change is accompanied by the production of heat, the latter being responsible for the familiar phenomenon known as self-heating in the mass of material. (2) The activity of plant enzymes, which results in a considerable portion of the protein in the green crop being broken down to the simple amino acids. (3) The activity of bacteria, which is responsible for the production of organic acids from the carbohydrate in the crop. The chief organic acids present in good silage are lactic acid and, to a smaller extent, acetic acid. In silage of inferior quality, the foul-smelling butyric acid is the predominant organic acid.

Silage may be used as a substitute for hay and roots in the rations of dairy cows and cattle. It is an excellent food for calves after weaning and is relished by sheep. It may also be fed, in moderation, to horses. The feeding value of good tower silage, considered on the basis of dry matter, is at least as high as that of hay made from the same green crop. It contains from 65 to 75 per cent. of moisture, and 100 lb. are equivalent to 30–40 lb. of hay, according to the quality of the hay. In this country, maize cannot in general be grown to the desired stage of maturity for purposes of ensilage, although at least one variety, the French Jaune Gros, has given very satisfactory results in the southern counties. The most uniformly successful results for silage are obtained with the oat and vetch crop, alone or in admixture with beans ([3]).

The Succulent Foods.—In Table VI. are given the composition and nutritive value of some of the common succulent feeding stuffs. Data for the by-products of the beet sugar industry are also included.

The introduction of root crops into this country during the 18th century was responsible for great improvements in the methods of

TABLE VI.—COMPOSITION AND NUTRITIVE VALUE OF SUCCULENT FOODS.

	Moisture %	Crude protein %	Oil %	Carbohydrate %	Fibre %	Ash %	Protein equivalent %	Starch equivalent %
Carrots	87·0	1·2	0·2	9·3	1·4	0·9	0·6	8·8
Kohl rabi	87·3	2·0	0·1	8·2	1·4	1·0	0·5	8·3
Mangolds (white-fleshed)	89·3	1·0	0·1	8·2	0·7	0·7	0·4	5·5
Mangolds (long red)	86·9	1·0	0·1	10·3	0·8	0·9	0·4	6·8
Swedes	88·5	1·3	0·2	8·1	1·2	0·7	0·7	7·3
Sugar beet	76·6	1·1	0·1	20·4	1·1	0·7	0·6	15·0
Turnips	91·5	1·0	0·2	5·7	0·9	0·7	0·4	4·4
Potatoes	76·2	2·1	0·1	19·7	0·9	1·0	0·9	17·8
Jerusalem artichoke	79·6	1·5	0·2	16·9	0·7	1·1	0·7	16·4
Dried sugar beet pulp	10·0	8·9	0·6	59·1	18·3	3·1	5·2	65·5
Molasses beet pulp ...	10·0	10.8	0·4	58·2	15·1	5·5	4·7	63·0
Beet molasses ...	25·3	3·5	—	66·0	—	5·2	1·2	51·6

animal husbandry, since they provided a valuable and highly digestible food which could be stored safely for the purpose of carrying stock over the winter. Roots are, in reality, diluted carbohydrate concentrates. Owing to their bulky, watery nature, it has been suggested that they should never be included in the rations of dairy cows. There can be no doubt, however, of their value in the feeding of dairy cows, provided they are fed in moderation, say from 30 to 50 lb. per head per day.

Roots contain a very high percentage of water, the dry matter content of mangolds, for example, varying from about 9 to about 14 per cent., according to variety. Swedes contain about 11·5 per cent. of dry substance, whereas the average dry matter content of sugar beet is about 25 per cent. The main food nutrient in root crops is carbohydrate, chiefly in the form of cane sugar. Roughly two-thirds of the dry matter consists of sugars, the rest being composed of pectose and small amounts of protein, fibre and ash.

Roots contain only small quantities of crude protein, the amount in mangolds, for example, being only 1 per cent. A large fraction of this, moreover, is not present in the form of true protein, but as nitrogenous substances of much simpler chemical nature, such as asparagine, ammonium salts and amino acids. The feeding value of these so-called " amides " has been the subject of many investigations. The Scandinavian scientist, Hindhede, has shown by experiments over long periods, that the digestible protein of potatoes, which are rich in " amides," is a valuable type of protein for building up body tissue. Experiments in Denmark have led to the conclusion that when dairy cows are fed on rations containing the correct requirements in respect of starch equivalent and digestible protein, almost 90 per cent. of the amides in the food are built up in the animal into milk protein. In Germany, Morgen has proved that if asparagine, a typical plant amide, be added to a ration containing sufficient starch equivalent but deficient in protein, then it can serve not only for maintenance, but also for milk production. At a later date, his fellow-countryman, Honcamp, obtained the surprising result that it is possible to replace part of the true protein in

the rations of dairy cows by means of an amide like urea without seriously affecting the milk yield of the animal.

When computing rations in this country, the "amides" are assumed to have a food value equal to half of that of the same amount of digestible true protein. It will be noted, in Table VI. that instead of stating the percentages of digestible protein for the succulent foods, figures for the so-called protein equivalent have been given. The protein equivalent is simply the percentage of digestible true protein plus half the difference between the percentages of digestible crude protein and digestible true protein. In the case of the succulent foods, the protein equivalents should be employed, instead of the percentages of digestible protein, for purposes of computing rations.

Mangolds are never used for feeding immediately after "pulling," since in this condition they cause "scouring" in the animals receiving them. After storage in the clamp until the end of December, however, they may be fed with perfect safety. During storage, a large proportion of the cane sugar in the mangolds undergoes inversion into the reducing sugars, fructose and glucose. Mangolds contain an oxidising enzyme, which is responsible for the rapid darkening of the juice on exposure to the air. They are a popular food for dairy cows, since they cause no taint in the milk. Fattening cattle are frequently given large allowances of mangolds (or swedes), in conjunction with hay, straw and oil cakes. They are also given to ewes and lambs in the spring, but should be fed only sparingly to male sheep, since they are liable to give rise to hard deposits in the bladder and ureters.

Both swedes and turnips are known to produce taint in milk, and it is essential, therefore, that they should be fed to dairy cows after, and never before, milking. Carrots, which contain about 13 per cent. of dry matter, including 9 per cent. of sugar, are liked by all kinds of stock, especially horses. Parsnips are usually grown for human consumption, but, where available for the purpose, may be used for feeding to dairy cows and bullocks. They contain about 15 per cent. of dry matter, including 11 per cent. of carbohydrate. Kohl rabi, although included with the roots in Table VI. is, in reality, a swollen stem. It possesses an advantage, from the feeding standpoint, over swedes and turnips, in that it does not taint the milk of dairy cows. Unlike mangolds, it can be fed to animals immediately after cutting.

Although it is neither customary, nor perhaps desirable, to utilize sugar beet for feeding purposes, it is conceivable that circumstances might arise occasionally when a farmer might wish to feed at least part of his crop. Sugar beets are too hard in texture to be used for feeding without previous pulping. It has been demonstrated that whole sugar beet, suitably grated, is an excellent substitute for barley meal, up to 25 per cent. of the total ration, in the production of bacon pigs. The substitution should be effected at the rate of 3½ lb. of grated sugar beet for 1 lb. of barley meal.

The pulp remaining in the factory after the extraction of the

sugar from the sugar beet contains from 93 to 95 per cent. of water. This is reduced by pressing to about 85 per cent., yielding the so-called wet sugar beet pulp. The latter can be used for feeding only on farms situated near to sugar factories, owing to the prohibitive cost of transport of such heavy, wet material and to the readiness with which it turns rancid and sour on exposure to the air.

Almost the whole of the wet pulp produced in the sugar factories is dried down artificially and sold under the name of dried sugar beet pulp. In some factories, a proportion of beet molasses is run on to the wet pulp before drying. The product, after drying, is known as molasses beet pulp and ordinarily contains about 20 per cent. of sugar.

Dried sugar beet pulp is a valuable food for dairy cows, fattening cattle and sheep. It is highly digestible and rich in digestible carbohydrate. It may be used as a substitute for roots in the ration, 1 lb. of dried pulp being able to replace 7 to 8 lb. of mangolds. It may be employed also as a substitute for cereals according to the following scheme : 1 lb. of dried sugar beet pulp = 1 lb. of oats = $\frac{9}{10}$ lb. of barley = $\frac{4}{5}$ lb. of maize. Fattening cattle may receive up to 10 lb. per head per day with safety ; dairy cows up to 8 lb. ; 3-month-old calves and ewes up to 1 lb. per head per day. Half the corn ration of horses has been replaced by a mixture of equal parts of dried beet pulp and molasses beet pulp with satisfactory results. Where more than small amounts of dried beet pulp are included in the ration, it is advisable that the food should be softened before use by soaking in twice its weight of water.

Molasses beet pulp may be regarded as having a food value for fattening stock equal to that of dried beet pulp. In the feeding of dairy cows, however, the ordinary dried beet pulp should be preferred to the molasses beet pulp, since the latter has been known in rare cases to produce a slight fishy taint in the milk.

Beet molasses, the syrupy residue remaining after crystallization of the sugar, contains from 15 to 30 per cent. of water, about 66 per cent. of carbohydrate, mainly sugar, and roughly 4 per cent. of albuminoid material, of which only about $\frac{1}{2}$ per cent. is in the form of true protein, the remainder consisting substantially of a useless nitrogenous substance known as betaine. The product contains no oil, but about 5 per cent. of ash, composed mainly of potash, with only a small amount of lime and no phosphoric acid. Beet molasses is used in the manufacture of molasses beet pulp and the various proprietary molasses foods. It can also be made use of for enhancing the palatability of chaff and palm kernel cake. If employed too liberally in the ration, however, it will cause " scouring " on account of its high content of alkaline salts.

The potato is the most important of the class of succulent foods known as tubers. On an average, it contains about 24 per cent. of dry matter, including 2 per cent. of crude protein, 20 per cent. of carbohydrate, mainly starch, and small amounts of fibre, oil and ash. Raw potatoes, if sound, clean and free from sprouts, may be

fed to cattle and dairy cows, but only in limited amount, owing to their tendency to produce "scouring." One pound of raw potatoes is equal to 2 lb. of swedes or mangolds. Dairy cows may receive up to 20 lb. per head per day, but cattle, in the fattening period, may be given twice this amount. They should never be fed to young stock or pregnant animals. Potatoes should always be cooked for pigs, 4 lb. of cooked potatoes being equal to 1 lb. of meal. One pound of dried potatoes has a food value equal to 1 lb. of barley or wheat. Fattening cattle may be given up to 10 lb. of the dried product per head per day, dairy cows up to 5 lb. and pigs 2½ lb. per 100 lb. live-weight.

The Concentrated Foods.—The farm concentrates are conveniently divided into three classes: (1) The leguminous and cereal grains; (2) the by-products of the cereal grains; (3) the oil cakes and extracted meals.

The composition and nutritive value of the common leguminous and cereal grains are shown in Table VII. (4).

TABLE VII.—COMPOSITION AND NUTRITIVE VALUE OF LEGUMINOUS AND CEREAL GRAINS.

	Moisture %	Crude protein %	Oil %	Carbohydrate %	Fibre %	Ash %	Digestible protein %	Starch equivalent %
Leguminous grains:								
Beans	14·3	25·4	1·5	48·5	7·1	3·2	20·1	65·8
Peas	14·0	22·5	1·6	53·7	5·4	2·8	19·4	69·0
Cereal grains:								
Barley	14·9	8·6	1·5	67·9	4·5	2·6	6·5	71·0
Maize	13·0	9·9	4·4	69·2	2·2	1·3	7·9	78·0
Oats	13·3	10·3	4·8	58·2	10·3	3·1	8·0	59·5
Rye	13·4	11·5	1·7	69·5	1·9	2·0	9·6	71·6
Wheat	13·4	12·1	1·9	69·0	1·9	1·7	10·2	71·6

The cereal grains are rich in carbohydrate, mainly starch, but deficient in protein. For the purpose of balancing such foods in the rations of farm animals, the farmer usually finds it necessary to buy supplies of protein-rich foods, such as oil cakes. Expenditure on the latter, however, may be reduced by making use of the home-grown protein concentrates, peas and beans. Beans contain more than 25 per cent. of protein, whilst peas contain about 23 per cent. Crushed beans are a popular food for pigs and influence the quality of the fat and flesh favourably. They may be included in the rations of dairy cows, and 2 to 3 lb. per head per day may, with excellent results, be given to fattening cattle. Whey is frequently supplemented, in the rearing of calves, by a mixture of four parts of linseed cake meal and five parts of finely ground bean meal, the mixture being used at the rate of 1 lb. to every gallon of whey, to which is added ½ oz. of feeding bone flour to provide the ingredients for bone formation. Crushed beans, in conjunction with maize, are a safe and valuable food for horses.

The cereal foods include the home-grown grains, wheat, barley, oats and rye, and the imported grains, maize and rice. In the feeding

of farm animals, they must essentially be regarded as sources of digestible carbohydrate, which is mainly in the form of starch. This is clear from an inspection of the data in Table VII. They are deficient in protein and ash, and the latter ingredient, though containing satisfactory amounts of potash and phosphoric acid, is exceptionally poor in lime and chlorine. Maize, wheat and barley contain about 0·05 per cent. of lime. With the exception of maize and oats, the cereals contain only a small percentage of oil.

Oats are the best balanced of the cereals, both in respect of the ratio of protein to starch and of lime to phosphoric acid. They are also fairly rich in oil and, owing to the inclusion of the husk, contain much more fibre than the other cereals. They are a popular and safe food for most kinds of stock, especially horses, but are usually considered too fibrous for feeding in more than moderate amount to growing pigs.

Wheat and barley are very similar in composition, being rich in starch, rather low in protein and containing only small amounts of fibre, oil and ash. The value of barley meal as a food for pigs is universally recognized ; for this purpose, it is supplemented with middlings, and the deficiency of ash and protein is made up by the inclusion of fish meal, or, alternatively, of an oil seed product, such as extracted soya bean meal, plus a mineral supplement. Wheat may replace barley up to about one-third of the whole ration, but total replacement is not advisable, since wheat tends to become pasty in the mouth during mastication, rendering swallowing a matter of difficulty. For this reason, it is better to crush the wheat instead of grinding it to a meal. The popularity of wheat as a food for poultry should be mentioned. The manner in which the home-grown cereals may be used for the various kinds of live-stock will be dealt with in greater detail in the section dealing with the requirements of farm animals.

Rye resembles wheat in composition, but is only grown in limited amounts in this country for feeding to farm stock. In its fresh condition, it is liable to produce digestive disturbance and is usually ground and scalded before feeding to pigs.

Maize, though containing a fair proportion of oil, is a very ill-balanced food and must be supplemented by feeding stuffs rich in protein and ash. When this precaution is observed, it is an extremely valuable ingredient of the rations of fattening animals. It should not be used too liberally for feeding to pigs, however, since it produces a soft, greasy fat.

Polished rice, which is sometimes ground for live-stock when not required for human consumption, is even richer than maize in respect of starch. It contains 78 per cent. of carbohydrate and only 6·7, 0·4 and 0·8 per cent. of protein, oil and ash respectively. It should be viewed solely as a food supplying digestible carbohydrate. Such ground rice should not be confused with rice meal, which consists substantially of the finely ground hulls of the rice kernel removed in the polishing process. Rice meal is much richer in oil, protein

and fibre than polished rice and is a better balanced food. It is frequently included in the rations of dairy cows and fattening cattle, but its richness in oil precludes its use with pigs.

In addition to the cereal grains already dealt with, mention should be made of buckwheat, millet and dari, which are imported in considerable quantities, mainly for feeding to poultry.

TABLE VIII.—COMPOSITION AND NUTRITIVE VALUE OF CEREAL BY-PRODUCTS.

	Moisture %	Crude protein %	Oil %	Carbohydrate %	Fibre %	Ash %	Digestible protein %	Starch equivalent %
Bran	13·0	15·1	3·8	52·8	9·5	5·8	10·9	42·6
Coarse middlings ...	14·0	15·8	4·9	56·8	4·9	3·6	11·5	58·3
Fine middlings ...	13·3	17·0	4·2	60·8	2·3	2·4	12·6	69·0
Flaked maize ...	11·0	9·8	4·3	72·5	1·5	0·9	9·4	84·0
Maize germ meal ...	12·0	10·0	11·0	59·0	7·0	1·0	9·0	79·0
Maize gluten meal ...	9·1	35·5	4·7	47·5	2·1	1·1	30·6	81·5
Maize gluten feed ...	10·4	23·5	3·4	56·7	3·5	2·5	20·0	75·6
Malt coombs... ...	10·0	24·4	2·0	42·4	14·0	7·2	19·9	43·4
Dried brewer's grains	10·3	18·3	6·4	45·9	15·2	3·9	13·0	48·3

Recent investigations into the grading and composition of wheat feeds, by which name the offals arising in the milling of wheat are now known, has revealed the fact that the old grade of pollards has disappeared as a result of changes during the period of governmental control of the milling industry during the Great War. Two main grades of wheat feeds are now sold on the market, namely, bran and coarse middlings, and only relatively small amounts of fine middlings are made. The coarse part of the pollards gets into the bran and the finer portion into the coarse middlings. Though the grading of the offals according to size of particles results in a division into three groups possessing sharply defined compositions, digestibilities and feeding values, as will be noted from the data in Table VIII., it is obligatory, when marketing the grades, to furnish a guarantee of fibre content, in order to prevent unscrupulous traders from grinding the coarser offals for admixture with the more expensive finer grades. It will be noted that the three grades are characterized by very different fibre contents, namely, 9·5, 4·9 and 2·3 per cent. for bran, coarse middlings and fine middlings respectively.

Bran is a popular food for live-stock because of its gently laxative properties. It is largely used for cattle and horses, but is too fibrous for use in more than small amount for growing pigs, although it is commonly included in the rations of in-pig sows. Growing pigs commonly receive middlings, in conjunction with feeding stuffs such as barley meal and fish meal.

Although the cooking of maize for pigs does not result in any significant increase in digestibility and nutritive value, it has been shown that the commercial process of steaming the grain, followed by rolling into thin flakes, leads to a distinct improvement in feeding value. Flaked maize is a highly digestible food and is well-suited for inclusion in the rations of deep-milking cows and of stock designed for early maturity. Maize gluten meal and maize gluten

feed, arising as by-products in the manufacture of corn flour and glucose from maize, are both rich in protein and are useful for increasing the protein content of the rations of all kinds of stock. Maize germ meal is much less rich in protein and has acquired considerable popularity as a supplementary food for grazing stock, for which purpose it is made in the form of cakes and cubes. It is too rich in oil for feeding to swine.

Brewer's grains may be purchased either wet or dry. The wet grains, however, can be used only on farms in the vicinity of breweries, owing to the readiness with which they turn sour and to considerations of transport. Dried brewer's grains may be fed to dairy cows and fattening cattle up to about 6 lb. per head per day, but are too fibrous for pigs. Malt coombs are a valuable food for dairy cows and young stock.

Oil cakes and extracted meals [5] are the residues which remain after the removal of the oil from certain oily seeds and fruits, such as cotton seed (24 per cent. oil), ground nuts (45 per cent. oil), linseed (37 per cent. oil), palm kernels (49 per cent. oil) and soya beans (18 per cent. oil). The oil thus obtained is used for the manufacture of soap and margarine. When the oil is removed by hydraulic pressure, the residues, known as oil cakes, contain on an average about 8 per cent. of oil. Extraction of the coarsely crushed seeds with solvents, such as petrol, naphtha and carbon bisulphide, leads to a more thorough removal of oil, and the resulting extracted meals contain only 1–2 per cent. of oil. The composition and feeding value of the better-known oil cakes and extracted meals are shown in Table IX.

TABLE IX.—COMPOSITION AND NUTRITIVE VALUE OF OIL CAKES AND EXTRACTED MEALS.

	Moisture %	Crude protein %	Oil %	Carbohydrate %	Fibre %	Ash %	Digestible protein %	Starch equivalent %
Coco-nut cake ...	11·4	20·7	9·9	41·4	11·2	5·4	16·2	79·1
Undec. cottonseed cake (Bombay) ...	12·3	20·2	4·8	35·2	21·7	5·8	15·6	40·0
Undec. cottonseed cake (Egyptian) ...	12·1	23·0	5·5	32·4	21·2	5·8	17·6	41·8
Dec. cottonseed meal	8·7	42·1	10·9	24·9	7·4	6·0	36·3	74·0
Dec. groundnut cake	10·3	46·8	7·5	23·2	6·4	5·8	42·0	73·0
Linseed cake ...	11·2	29·5	9·5	35·5	9·1	5·2	25·3	74·0
Palm kernel cake ...	11·0	18·8	7·7	45·3	13·4	3·8	17·1	74·9
Extr. palm kernel meal	10·0	19·0	2·0	49·0	16·0	4·0	17·1	71·3
Soya bean cake ...	14·5	42·4	7·0	25·8	5·0	5·3	38·2	69·1
Extr. soya bean meal	11·3	44·7	1·5	31·9	5·1	5·5	40·3	64·0

The oil cakes and extracted meals are the most important of the class of feeding stuffs known as protein concentrates. Coco-nut cake is the residue remaining after crushing the oil from copra, the dried fleshy interior of the coco-nut. It is a valuable food for dairy cows and fattening bullocks and, after grinding to a meal, is frequently employed in pig-feeding. Cottonseed cake comes on to the market in the undecorticated and decorticated forms. The

undecorticated varieties contain all the hulls of the seed and varying amounts of the lint. They contain, therefore, a large percentage of fibre, amounting to about 21 per cent. and, relatively speaking, only a small amount of protein, namely, from 20 to 23 per cent. Decorticated cottonseed cake, made by crushing seeds which have been freed from hulls, has a much higher protein content and feeding value than the undecorticated cake. It is frequently ground to a meal and sold under the names of decorticated cottonseed meal or yellow meal. The astringent properties of undecorticated cottonseed cake have made it popular for adding to the rations of cattle on lush pasture or on heavy root allowances. This property is shared, to a lesser degree, by the decorticated product. Both the decorticated and undecorticated products are favourite foods for use with sheep and cattle, but the undecorticated cottonseed cake, on account of its high fibre content, should not be fed to young stock.

Ground nut cake is manufactured by crushing the oil from ground nuts (earth nuts, peanuts, monkey nuts). The undecorticated variety has a somewhat higher feeding value than undecorticated cotton cake, but does not possess the astringent properties of the cottonseed product. Decorticated ground nut cake is particularly rich in protein and is a safe food for all kinds of stock, if used in moderation and balanced against carbohydrate-rich foods, such as cereals.

Linseed cake is a safe and popular food for live-stock and is highly prized for feeding to fattening cattle in the final stages of feeding. No other food confers in such degree the "bloom" and sleekness of coat favoured by the butcher. It is a valuable food for young stock. On account of its gently laxative action, linseed cake is useful for introducing into mixtures which otherwise might have a constipating effect on the animal. Whole linseed is sometimes crushed to a meal and used, in small amount, for feeding to sick animals or for adding to skimmed milk, in replacement of cream, in the feeding of calves. Linseed cake should be used with care when being fed to porkers or baconers, owing to its tendency to produce an oily fat.

Palm kernel cake is a valuable feeding stuff for dairy cows, cattle and pigs. When first introduced into the ration, however, animals do not take to it readily. This difficulty is only temporary, and may be overcome by accustoming stock to it gradually and increasing its palatability by the inclusion of a little tasty food, such as molasses or locust bean meal.

Soya bean cake, containing more than 40 per cent. of protein, compares with decorticated cottonseed and ground nut cakes in respect of its richness in this constituent. It has a slight laxative action and is a safe food for all kinds of stock, if fed in moderation and balanced with foods rich in carbohydrate. Extracted soya bean meal, containing only about 1·5 per cent. of oil, is, when supplemented with minerals, an efficient substitute for fish meal in the feeding of pigs.

Among the lesser-used oil cakes may be mentioned rape cake (containing 36 per cent. of protein and possessing an unpleasant, bitter taste), sesame cake (containing 45 per cent. of protein and having a good reputation on the continent for feeding to dairy cows) and sunflower cake (37 per cent. of protein).

Miscellaneous Concentrated Feeding Stuffs.—Of the materials which have been added to the list of pig-feeding stuffs in recent years, special interest attaches to white fish meal. The latter is defined as "a product (containing not more than 6 per cent. of oil and not more than 4 per cent. of salt) obtained by drying and grinding or otherwise treating waste of white fish, and to which no other matter has been added." It contains more than 50 per cent. of protein and about 20 per cent. of mineral matter, the latter being composed mainly of phosphate of lime. Fish meal is an excellent supplement to grains and grain offals, because it supplies an abundance of digestible protein and minerals, in both of which the cereals grains are deficient. Owing to its high protein content, the ration of the pig should not contain more than small amounts of fish meal.

A second grade of fish meal is made from the refuse of herrings, mackerel and other oily fish. Such fish meal, containing 10 to 20 per cent. of oil and frequently large amounts of salt, should not be used for feeding purposes on account of risk of taint.

Dried blood, a product of the slaughter-house, is a dark brown powder containing about 80 per cent. of protein. It is a useful supplement to grains and wheat offals in the rations of young swine, but should be fed in very small amounts (1 to 2 oz. per day) on account of its richness in protein.

Meat meal is produced by drying and grinding the refuse, other than bones, in factories where meat is canned or where meat extract is made. It contains 70 per cent. of protein and 10 to 15 per cent. of fat. Carcass meal is obtained when the bones are ground up with the refuse meat. It contains 50 per cent. of protein, 10 to 15 per cent. of fat and about 20 per cent. of mineral matter. The latter, as with fish meal, consists mainly of phosphate of lime.

Dried yeast, which results from the drying of waste yeast from the breweries, contains about 50 per cent. of protein and practically no oil and fibre. It is particularly rich in vitamin B. On account of its richness in protein, it should be fed only in small quantities, and in the diet of the pig not more than 4 to 8 oz. should be included.

Large quantities of manioc meal (tapioca flour), a by-product of the cassava root, are now finding their way on to the market. This feeding stuff is essentially to be regarded as a source of digestible carbohydrate, and it should only be fed to pigs in conjunction with protein and mineral supplements. It contains 81 per cent. of carbohydrate, mainly starch, and only 3 per cent. of protein. It has been shown to be suitable for replacing maize meal or barley meal up to at least 25 per cent. of the pig's total ration.

Requirements of Farm Animals (2).—The science of animal nutrition is mainly concerned with the securing of such information as will render possible the efficient and economic feeding of farm animals. Research in this branch of biological science is directed towards the solution of the following problems : (1) What are the energy and protein requirements of the different classes of farm animals at the different stages of their life-histories ? (2) What are the capacities for food consumption of farm animals at different ages and live-weights ? (3) What are the capacities of the available feeding stuffs for supplying the requirements of farm animals ? Information relative to the feeding values of the different feeding stuffs of the farm has already been brought forward in the preceding sections of this chapter. It has been made clear that the nutritive value of a food can be defined in terms of its content of digestible protein and starch equivalent. It now remains to consider the information which has been accumulated by various workers respecting the food requirements of farm animals.

It is customary, in the feeding of live-stock, to distinguish between two kinds of requirements : (1) maintenance requirements and (2) production requirements. A maintenance ration is one which will maintain a resting animal in health, without losing or gaining in weight. Scientifically speaking, the animal, on such a diet, should be in carbon and nitrogen equilibrium, or, translated into popular language, it should neither be gaining nor losing fat and flesh. A maintenance ration provides sufficient starch equivalent for keeping the body temperature at about 37° C., for furnishing the energy necessary for the involuntary activities of the body, such as heart beat and blood circulation, and for enabling the animal to perform such small amounts of work as are entailed in lying down, standing up or walking about. In addition, the ration should supply a certain minimum amount of digestible protein to make good the losses of protein from the body as a result of the " wear and tear " of the cells in the living processes.

Any food fed beyond the maintenance requirements can be used for productive purposes, such as milk production, live-weight increase and muscular work. The amount of food to be added to the maintenance ration depends on the rate of production in the animal. Thus, if the live-weight increase in a bullock is g lb. per day, and each lb. of live-weight increase contains c lb. of starch equivalent, then the production requirement is gc lb. of starch equivalent. Similarly, if a dairy cow is yielding n gallons of milk daily, and each gallon of milk contains e lb. of starch equivalent, then the requirement for milk production is ne lb. of starch equivalent.

With meat-producing animals, the ration R, in terms of starch equivalent, is calculated according to the expression : $R = M + gc$, where M is the maintenance requirement of the animal, g its rate of gain of live-weight in lb. per day and c the starch equivalent contained in 1 lb. of live-weight increase. The ration must be made

up so as to furnish a certain minimum amount of digestible protein. In the case of cattle, the maintenance requirements have been determined by balance experiments on fully-grown oxen in respiration chambers, while the starch equivalent requirements per lb. of live-weight increase at different ages and live-weights have been found by a method of experimentation known as the comparative slaughter method.

The computation of rations for dairy cows is carried out in a similar manner: R, the starch equivalent of the total ration, is equal to M, the maintenance requirement, plus *ne*, where *n* equals the yield of milk per day in gallons and *e* is the starch equivalent content, or requirement, per gallon. As with meat-producing animals, the rations for dairy cows must furnish a definite amount of digestible protein. The maintenance requirement of dairy cows are assumed to be the same as those for bullocks of similar live-weight.

It must not be thought that this method of computing rations necessarily gives results in mathematically exact agreement with an animal's actual requirements. This could not possibly be so, since animals are not machines, but are characterized by varying individualities. The method, however, affords a very safe guide to economic feeding, and the art and skill of the feeder will be employed in making any slight adjustments which he may deem necessary on the basis of his observations of the progress of his animals.

The Requirements for Milk Production (6).—In Table X. are summarized the food requirements of dairy cows, in terms of digestible protein and starch equivalent.

TABLE X.—FOOD REQUIREMENTS OF DAIRY COWS.

	Live-weight of Animal.	Starch equivalent.	Digestible protein.
	cwt.	lb.	lb.
Maintenance:	10	6·50	0·70
	12	7·50	0·75
	14	8·25	0·80
Production (per gallon of milk):—			
(*a*) Jersey and Guernsey breeds ...	At all live-weights.	3·0	0·7
(*b*) All other breeds	" "	2·5	0·6

Rations composed of feeding stuffs such as hay, straw, roots, silage, dried sugar beet pulp, etc., are usually employed to satisfy the maintenance requirements of dairy cows. The following rations, containing about 6·5 lb. of starch equivalent and including about 0·7 lb. of digestible protein, may be taken as typical maintenance rations for a dairy cow of 10 cwt. live-weight: (1) 18 lb. of average meadow hay; (2) 13 lb. average meadow hay plus 40 lb. mangolds; (3) 15 lb. oat and vetch silage, 4 lb. oat straw and 10 lb. average meadow hay.

An amount of food containing 2·5 lb. of starch equivalent and including 0·7 lb. of digestible protein is required for the production

of a gallon of average milk (3·7 per cent. of fat), such as is given by shorthorn cows. A four-gallon cow of 10 cwt. live-weight requires, therefore, a ration which supplies $6{\cdot}5 + (2{\cdot}5 \times 4) = 16{\cdot}5$ lb. of starch equivalent, including $0{\cdot}7 + (0{\cdot}6 \times 4) = 3{\cdot}1$ lb. of digestible protein. In the case of Jersey and Guernsey cows, yielding milk which contains, on an average, 4·9 per cent. of fat, the production requirement, per gallon, rises to 3 lb. of starch equivalent, including 0·7 lb. of digestible protein.

Concentrated feeding stuffs, such as oil cakes and extracted meals balanced by cereals and cereal by-products, are most commonly used in the production part of the rations of dairy cows. The proportion of cereal which can be used in the production mixture depends on the kind of oil cake used. If the latter is extremely rich in protein, as is the case with decorticated ground nut cake, then two parts by weight of cereal may be mixed with one part of oil cake. This fact is illustrated by the example worked out in Table XI.

TABLE XI.—MILK-PRODUCTION RATION CONTAINING BARLEY AND DEC. GROUND NUT CAKE.

	Starch equivalent.	Digestible protein.
	lb.	lb.
100 lb. dec. ground nut cake contain	73·0	42·0
200 lb. barley contain	142·0	13·0
300 lb. mixture contain	215·0	55·0
100 lb. " "	71·7	18·3
3½ lb. " "	2·5	0·64

It will be seen that 3½ lb. of a mixture of one part of decorticated ground nut cake and two parts of barley supply the starch equivalent and digestible protein necessary for the production of a gallon of milk. The production mixture may be varied by replacing the decorticated ground nut cake, wholly or partly, by oil cakes similarly rich in protein, such as decorticated cottonseed meal, soya bean cake and sesame cake. Further variation may be effected by the replacement of the barley, wholly or in part, by other starchy foods, such as maize, flaked maize, wheat and fine middlings.

When oil cakes less rich in protein are employed in the milk-production mixtures, the proportion of cereal must be reduced in order to preserve the correct balance. For example, a mixture of two parts by weight of linseed cake and one part of barley, when used at the rate of 3½ lb. per gallon, supplies the requisite 2·5 lb. of starch equivalent, including 0·6 lb. of digestible protein. The oil cake in the production mixture, however, should never consist wholly of linseed cake, firstly, on account of the dearness of this feeding stuff, and secondly, because the too-liberal use of linseed cake tends to produce a soft, greasy texture in the butter from the milk. It is advantageous, therefore, to combine the linseed cake—

cereal mixture with one, two or three parts of the decorticated ground nut cake (or decorticated cottonseed meal)—cereal mixture, and to feed 3½ lb. of the resulting mixture for every gallon of milk.

It is interesting to note that palm kernel cake has the correct balance for milk production, 3½ lb. of this oil cake containing 2·6 lb. of starch equivalent, including 0·6 lb. of digestible protein. It may be fed in the production ration, therefore, without admixture with cereals, or may be added to any other milk-production mixture without disturbing the balance between starch equivalent and digestible protein.

The method of computing rations for dairy cows outlined above depends on making a definite allowance of food, usually in the form of roughage, alone or admixed with other bulky foods such as roots and sugar beet pulp, for purposes of maintenance, and then adding on 3½ lb. of a balanced concentrate mixture for every gallon of milk. If, as is commonly the case, the maintenance ration takes the form of 20 lb. of meadow hay of moderate quality, then a four-gallon cow will receive $20 + (3\frac{1}{2} \times 4) = 34$ lb. of food per day. This figure is of particular interest, since it is assumed to mark the capacity for food consumption of 10 cwt. dairy cow. In terms of dry matter, it amounts to about 30 lb. per day. Obviously, therefore, this method of computing rations breaks down when dealing with cows yielding more than four of five gallons of milk daily. A seven-gallon cow, for example, cannot cope with a daily ration containing $20 + (3\frac{1}{2} \times 7) = 44\frac{1}{2}$ lb. of food.

With high-yielding cows, there is no alternative but to cut down the amount of coarse fodder in the ration, so as to keep the total ration in the neighbourhood of 34 lb. per day. The requirement of concentrated food for milk production is first calculated and this amount is subtracted from 34 lb., the difference giving the amount of hay which should be included in the ration. In the case of the seven-gallon cow, the concentrate allowance is $3\frac{1}{2} \times 7 = 24\frac{1}{2}$ lb.; the hay allowance is $34 - 24\frac{1}{2} = 9\frac{1}{2}$ lb. per day. This method of computing the hay allowance for high yielders appears to work satisfactorily in practice and can be justified on theoretical grounds. It should be kept in mind, however, that heavy-yielding cows are frequently characterized by an ability to consume much more than 30 lb. of dry matter in their daily food.

Requirements for Beef Production.—The greater proportion of young cattle in the British Isles pass through a long store period, of two to two-and-a-half years, on the pastures of Ireland, Wales and the western counties. At the end of the store period, they weigh from 7 to 10 cwt., having gained, since birth, at the rate of about 1 lb. live-weight per day. A higher rate of gain is not possible, since such animals are on grass of indifferent quality during the summer and are usually fed on poor hay in the winter. At the end of the store period, the beasts go through an intensive period of feeding of 3 to 4 months, after which they are slaughtered as prime beef. Store beasts are fattened on roots, straw and hay, and

concentrates in East Anglia, or may be fed, for the same purpose, on the rich pastures of the Midlands.

In recent years, however, there has been a strong movement in the direction of feeding young beasts for early maturity, such animals, weighing in the neighbourhood of 10 cwt., being slaughtered for "baby beef" when about 18 months old. In this way, the overhead charges for maintenance food are reduced materially and the present demand for small, succulent joints is met. In the rearing of calves for "baby beef," advantage is taken of the fact that a calf is capable of increasing in live-weight at the rate of about 2 lb. per day. Such calves receive new milk for the first few weeks, followed by skim milk with a cream substitute. Later, they are brought on to hay, supplemented by cake and oats. In the winter, they are allowed a small ration of roots, kale or cabbage, with hay and concentrates. In the summer, while at grass, they receive a concentrated supplement, such as a mixture of crushed oats, malt coombs and maize germ meal. At a year old, they are fattened on roots or green stuff, hay and concentrates.

Feeding for quick maturity implies the liberal use of concentrated foods of high digestibility. Interesting figures have been published recently illustrating the different kinds of feeding which must be adopted for the production of prime beef and "baby beef." (7) A bullock fattened and killed at three years old has eaten, since birth, 18,000 lb. of dry matter, including about 1,000 lb. of concentrates. His carcass yields 800 lb. of saleable meat. He has, therefore, consumed, per lb. of saleable meat, 22½ lb. of dry matter, of which only 1¼ lb. is concentrated food. A "baby beef" animal, killed at eighteen months of age, has eaten 7,000 lb. of dry matter, of which 1,500 lb. consists of concentrates. His carcass yields 600 lb. of saleable meat. He has, therefore, consumed, per lb. of saleable meat, 11¾ lb. of dry matter, of which 2½ lb. is concentrated food. These figures show that, per lb. of meat produced, "baby beef" requires about twice as much concentrated foods as three-year-old beef.

A store beast of 8 cwt. live-weight requires 5½ lb. of starch equivalent per day for purposes of maintenance. This requirement rises to 6, 6½, 7, 7½ and 7¾ lb. of starch equivalent for bullocks of 9, 10, 11, 12 and 13 cwt. live-weight respectively. The production requirements for fattening, per lb. of live-weight increase, are as follows: (1) 2 to 2¼ lb. of starch equivalent for stores under 2 years. (2) For 2-year-old stores, 2¼ to 2½ lb. of starch equivalent, according to the condition of the animals. (3) 2½ to 2¾ lb. of starch equivalent for 2½ to 3-year-old stores. In the half-fat condition, a bullock requires, in addition to its maintenance food, 3 lb. of starch equivalent per lb. of live-weight increase, while if feeding is continued to the stage of fatness, it is necessary to supply about 4 lb. of starch equivalent to secure a lb. of live-weight gain. In this connection, it is of interest to recall that 4 lb. of digestible starch or starch equivalent has been shown by Kellner to form 1 lb. of fat in the body

of fattening bullocks. The foregoing data emphasize the well-known fact that it is uneconomical to push an animal to a state of absolute fatness, the food requirements in the final stages being excessive.

In respect of protein requirements, the rations of fattening bullocks need not contain more than 1½ lb. of digestible protein per day. The necessary starch equivalent should be contained in a bulk of food within the animal's capacity for food consumption, which varies from about 21 lb. of dry matter per day for the 8 cwt. store to about 28 lb. in the case of a beast of 13 cwt. live-weight.

A store beast of 9 cwt. live-weight requires, for live-weight increase at the rate of about 2 lb. per day, a ration supplying 6 lb. of starch equivalent for maintenance and $2\frac{1}{2} \times 2 = 5$ lb. for production purposes. The total ration should supply, therefore, 11 lb. of starch equivalent, including 1½ lb. of digestible protein, and this amount of nutrient should be contained in about 22 lb. of dry matter. An example illustrating the computation of such a ration is worked out in Table XII.

TABLE XII.—RATION FOR A 9 CWT. STORE BEAST FATTENING AT THE RATE OF 2 LB. PER DAY.

	Dry matter (lb.)	Starch equivalent (lb.)	Digestible protein (lb.)
50 lb. swedes	5·8	3·65	0·35
8 lb. oat straw	6·9	1·60	0·08
5 lb. meadow hay	4·3	1·85	0·27
4 lb. crushed barley	3·4	2·84	0·26
1 lb. bean meal	0·9	0·66	0·20
1 lb. dec. cottonseed meal ...	0·9	0·74	0·36
Total ration	22·2	11·34	1·52

Such a ration would enable the animal to increase in live-weight at the rate of about 2 lb. per day. As the beast increased in weight, it would be necessary from time to time to increase the size of the ration. The extra food, however, should not consist of oil cake, since the animal is already receiving as much digestible protein as is necessary. For this purpose, home-grown cereals or maize, raw or flaked, should be employed. If the stock feeder wishes to use linseed cake during the last month of fattening, in order to improve the appearance of his animals, then 2 lb. of linseed cake may be introduced into the rations in replacement of 1 lb. of barley + 1 lb. of decorticated cottonseed meal.

In computing rations for young cattle designed for early maturity, it should be kept in mind that the gain in live-weight in very young animals consists mainly of water, protein and ash. As the animals grow older, the live-weight gain becomes less watery and progressively richer in fat, and it follows, therefore, that the starch equivalent required, per lb. of live-weight increase, grows steadily larger with advancing age. The production requirement varies from 1·3 lb. of starch equivalent at 2 to 3 months. 1·6 lb. at 3 to 6

months, 1·9 lb. at 6 to 9 months, up to 2·1 lb. at 9 to 12 months of age. The maintenance requirements are 4, 4½ and 5 lb. of starch equivalent at 5, 6 and 7 cwt. live-weight respectively, the corresponding capacities for consumption being 14½, 17 and 19 lb. of dry matter per day.

As an illustration of the method of computing rations for early maturity, the case of a 10-months-old steer intended for "baby beef" may be considered. Such an animal, weighing about 6 cwt., requires 4½ lb. of starch equivalent for maintenance. In order that it may increase in live-weight at the rate of about 2 lb. per day, it should receive a further allowance of food supplying 2·1 × 2 = 4·2 lb. of starch equivalent. The total ration, therefore, should contain 8·7 lb. of starch equivalent, including about 1¼ lb. of digestible protein, and this amount of nutrient should be contained in not more than about 17 lb. of dry matter. A suitable ration is computed in Table XIII.

TABLE XIII.—RATION FOR A 10-MONTHS OLD STEER INTENDED FOR "BABY BEEF."

	Dry matter (lb.)	Digestible protein (lb.)	Starch equivalent (lb.)
10 lb. good meadow hay	8·6	0·54	3·70
40 lb. swedes	4·6	0·28	2·92
1 lb. barley meal	0·9	0·06	0·71
1 lb. bean meal	0·9	0·20	0·66
1 lb. linseed cake	0·9	0·25	0·74
Total ration	15·9	1·33	8·73

Requirements of Sheep (2).—The information which has been secured in recent investigations into the food requirements of sheep is summarised in Table XIV.

TABLE XIV.—FOOD REQUIREMENTS OF SHEEP. (*Taken from "Rations for Live Stock."*)

Live-weight (lb.)	Appetite in lb. dry matter per week.	For maintenance: lb. starch equivalent per week.	For production: lb. starch equivalent per lb. of live-weight increase.	Digestible protein lb. per week.
20	8	3	1	¾
40	13	4½	1¼	1
60	17	6¼	1½	1⅛
80	21	7¾	1¾	1¼
100	24	9	2	1⅜
120	27	10	2½	1½
140	30	11	3	1⅝
160	33	12	3½	1¾

As an instance of the use to which the data in Table XIV. may be put, the case of the winter fattening of tegs (hoggetts) may be dealt with. Such animals will average about 80 lb. live-weight when folded in October, and they will be expected to increase in live-weight at the rate of about 2½ lb. per head per week. Table XIV.

furnishes the data necessary for computing a suitable ration for this purpose. A teg of 80 lb. live-weight requires, for maintenance, an amount of food supplying $7\frac{3}{4}$ lb. of starch equivalent per week. Extra food, containing $1\frac{1}{2} \times 2\frac{1}{2} = 3\frac{3}{4}$ lb. of starch equivalent, must be given to make possible a live-weight gain of $2\frac{1}{2}$ lb. per week. The total weekly ration should therefore contain $11\frac{1}{2}$ lb. of starch equivalent and should include about $1\frac{3}{4}$ lb. of digestible protein. The starch equivalent should be contained in not more than 21 lb. of dry matter.

If the tegs are folded on marrow stem kale and are allowed, in addition, 5 lb. of seeds hay per head per week, the consumption of kale will average about 100 lb. per head per week. Reference to tables giving the composition and nutritive value of feeding stuffs shows that this amount of kale and seeds hay will supply 18·6 lb. of dry matter, containing 10·4 lb. of starch equivalent and 1·6 lb. of digestible protein. The tegs, therefore, should receive, per head per week, a supplement containing 1·1 lb. of starch equivalent, including 0·15 lb. of digestible protein, and this should be supplied in not more than $2\frac{1}{2}$ lb. of dry matter.

The best kinds of feeding stuffs for supplementary feeding to fattening sheep are cereals, such as crushed barley, maize meal, etc., fed in conjunction with oil cake meals. 1·5 lb. of a mixture of one part by weight of decorticated cottonseed meal and two parts of crushed barley contains the necessary 1·1 lb. of starch equivalent and includes about 0·2 lb. of digestible protein. The supplement should be fed at the rate of about $\frac{1}{4}$ lb. per day for the first month, the amount being increased gradually during the feeding period to about $\frac{3}{4}$ lb. per head per day.

For the production of every gallon of milk, a suckling ewe should receive, in addition to its maintenance requirements, extra food containing 3 lb. of starch equivalent, including 1 lb. of digestible protein. This amount of nutrient is contained in 4 lb. of linseed cake, or in 4 lb. of a mixture of equal parts of barley (or other cereal) and decorticated ground nut cake (or similarly protein-rich oil cake). Investigations of the milk yield of Suffolk ewes has revealed the fact that such animals give about $2\frac{1}{2}$ gallons of milk per week, ewes with doubles yielding rather more and ewes with singles rather less. The milk-production requirement of a ewe, therefore, is about $2\frac{1}{2} \times 3 = 7\frac{1}{2}$ lb. of starch equivalent, including 3 lb. of digestible protein per week. This is contained in 10 lb. of the mixture of equal parts of barley and decorticated ground nut cake. If, however, the ewes, with their lambs, are folded on thousand headed kale and are given 14 lb. of seeds hay per head per week, then they will secure a part of their production requirements from these fodders, and a suitable supplement, per head per day, will be rather less than 1 lb. of a mixture of one part of decorticated cottonseed meal and two parts of crushed oats.

The Summer Feeding of Sheep and Cattle.—The application of scientific principles, as embodied in the feeding standards, to the

nutrition of live-stock is a relatively simple matter during winter, since during this season the farmer is able to control the amount of food consumed by his animals, and moreover, the composition and nutritive value of such foods as are commonly employed in winter feeding can be assessed with a fair degree of reliability. During summer, however, when sheep and cattle are out on pastures, it is not easy to ensure that the feeding of farm animals is being carried out in accordance with the accepted standards.

In the first place, it is difficult to judge the amount of grass consumed in a day by a grazing animal, and most figures given in this connection must be regarded as unreliable. The tendency of animals to " scour " on spring pasturage is probably to be explained by their going from restricted indoor feeding to unrestricted outdoor feeding, under which conditions they are liable to consume excessive amounts of the abundant, protein-rich herbage. In the second place, the composition of pasture herbage is extremely variable during the course of the season, especially under ordinary conditions of extensive grazing. Only when pastures are intensively grazed, as in the modern system of sectional grazing, is it possible to assess the composition and nutritive value of the herbage with any degree of precision. In the third place, grazing animals use up very significant amounts of energy in biting off the grass and in walking about the pastures. It has been suggested that, on the best fatting pastures, the amount of energy thus used up by cattle amounts to about 1 lb. of starch equivalent per head per day, whereas on the poor types of grassland, it may be as high as 3 lb. of starch equivalent. During the hot part of the season, animals on pastures also expend considerable energy in warding off the attacks of flies and other insects. The conditions of summer feeding, it will be noted, do not by any means conform to the restful, indoor conditions under which the requirements of farm animals have, for the most part, been determined.

The efforts of the stock-feeder, during summer, are mainly directed towards deciding when supplementary feeding on grass is necessary, and, when necessary, what kinds and amounts of concentrates should be used for the purpose. Recent investigations have shown that young, leafy grass is exceedingly rich in protein and starch equivalent. The dry matter in such herbage is to be regarded as a protein concentrate of high digestibility and nutritive value. It contains about 70 per cent. of starch equivalent, including about 20 per cent. of digestible protein. A ration of such grass containing 30 lb. of dry matter (*i.e.*, an amount assumed to be a measure of the appetite of a 10 cwt. dairy cow) supplies about 21 lb. of starch equivalent, including about 6 lb. of digestible protein ; that is to say, sufficient starch equivalent for the production of six gallons of milk and enough digestible protein for nine gallons. It may be concluded with safety that young, leafy grass contains starch equivalent sufficient for five gallons of milk and digestible protein sufficient for seven gallons.

These figures indicate that such herbage is not correctly balanced for milk production, owing to its richness in protein. The correct supplement for dairy cows, therefore, should be rich in carbohydrate and poor in protein, a statement which also holds good for fattening stock and young animals. A balanced ration for young beasts, for example, is obtained by supplementing nine parts by weight of fresh grass with one part of starchy food.

In the spring, when pastures are covered with an abundant growth of leafy herbage, supplementary feeding should be unnecessary, under conditions of intensive grazing, for animals yielding less than five gallons of milk per day. The supplement for higher-yielding cows should take the form of starchy foods, such as home-grown cereals or maize germ cubes, and not oil cakes, such as cotton cake, which has been much favoured in the past for this purpose on account of its astringent properties. It may, at some future date, be found feasible to utilize intensively-grazed grass in a manner similar to that in which winter protein concentrates are employed. This would imply restricting grazing to such periods as would permit animals to satisfy their requirements for digestible protein, their further requirements being supplied in the form of hay and starchy concentrates.

When pastures are closely-grazed at regular intervals (sectional grazing), the high protein content and feeding value do not fall off to any great extent as the season advances. Under a system of close-grazing at monthly intervals, for example, the herbage from May onwards contains, on the basis of dry matter, 66½ per cent. of starch equivalent, including 13 per cent. of digestible protein. A ration of such herbage containing 30 lb. of dry matter furnishes the requirements of a 5-gallon cow for starch equivalent and digestible protein. Changes in the productivity of the pastures should be watched carefully, however.

Supplementary foods, if the pastures continue to grow satisfactorily should still be given in the form of cereals and cereal by-products. Should, however, the pastures become "scorched" by continued heat and drought, it may be necessary to resort to drought-resisting crops, such as lucerne, or even to help out the brown, scanty herbage with such winter foods as hay, silage and balanced concentrate mixtures.

Under ordinary conditions of extensive grazing, pastures are often left rough and fibrous in the autumn, and this reduces their feeding value in the following spring. On such pastures, it is advisable to feed supplementary food, in the form of starchy products, to dairy cows yielding more than three gallons of milk per day. As the season advances, extensively grazed pastures become coarse and stemmy and of greatly diminished feeding value. Supplementary feeding, during late summer and autumn, may be needed for each gallon of milk under such conditions, and the supplement should consist of a balanced milk-production mixture.

Requirements of Horses.—Only scanty information is available,

unfortunately, on which to base standards for the rationing of horses. A heavy farm horse, weighing about 15 cwt., needs about 20 lb. of good hay for purposes of maintenance. In addition to this allowance of food, it requires a production ration in keeping with the amount of work it performs during the day. This additional food is given in the form of concentrates, usually fairly rich in carbohydrate, since it is this constituent which is most useful for furnishing the energy required for muscular activity. The most suitable concentrated food for horses is oats, an average oat ration for a heavy farm horse being about 12 lb. per day.

For light work, a heavy farm horse should receive, in addition to its maintenance allowance of hay, about 7 lb. of oats per day ; for medium work, about 11 lb., and for heavy work, about 16 lb. Manifestly, however, it is not easy to define exactly what is meant by the terms light, medium and heavy work, but it is possible, by careful observation of the condition of the animal, to ensure that it is being fed correctly. If the animal displays a tendency to lose flesh, the oat ration should be increased ; if, on the other hand, it tends to become fat, the oats should be reduced accordingly.

When, for purposes of variety or economy, it is desired to replace part of the oat ration by other concentrates, this should be done on the following basis : 10 lb. of oats = 7·3 lb. of maize = 9 lb. of beans = 8·3 lb. of barley = 12·3 lb. of dried brewer's grains = 13·2 lb. of bran.

Requirements of Swine.—Rations for pigs are usually composed of a large proportion of cereal, in admixture with middlings and a relatively small amount of food rich in protein, the last-named being included to make good the deficiency of the cereal in this respect. When white fish meal is not employed as the source of protein, it is usually necessary to include 2 to 3 per cent. of a suitable mineral mixture in the ration, in order to furnish the constituents required for bone formation. The main mineral deficiencies in the cereals are lime and chloride, but not phosphoric acid and potash, so that the essential components of a pig mineral mixture are chalk and common salt. It is assumed that the addition of minerals is unnecessary when the ration contains 10 per cent. or more of fish meal.

The most valuable and popular cereal for use in pig-feeding is barley meal. The latter, when it is desired on the grounds of economy, may be replaced in part by such carbohydrate-rich foods as maize meal, flaked maize, ground rice, ground oats, crushed wheat, cooked potatoes and tapioca flour. White fish meal, the protein-rich component of the diet, may be replaced by such foods as extracted soya bean meal, extracted ground nut meal, palm kernel cake meal, extracted palm kernel meal, coco-nut meal, maize gluten meal, bean meal, pea meal, dried blood, meat meal and whale meat meal. In general, extracted meals are more suitable for pigs than oil cake meals, on account of their lower oil content. In all cases, with the exception of fish meal, which is rich in lime and phosphoric

acid and also contains a sufficiency of common salt, *the use of these protein-rich foods for pigs will give good results only if fed in* conjunction with minerals. Milk and its *liquid by-products* are valuable foods for pigs, and they can be obtained in dried and semi-dried forms, such as dried milk (whole or separated), condensed milk (whole or separated), dried or semi-dried buttermilk, whey paste and dried whey. The importance of giving pigs a small daily allowance of fresh green food, for the purpose of supplying vitamins, should be emphasized.

A pig at birth averages about 2½ lb. live-weight. In the first ten days of life, it increases at the rate of about ¼ lb. per day, and very soon the rate increases to about ½ lb. per day. At 80 to 100 lb. live-weight, his rate of growth is about 1 lb. per day, increasing as he grows larger to 1½ and even 2 lb. per day. A pig which has attained a live-weight of 200 lb. at seven months has made an average rate of gain of live-weight over the whole period of nearly 1 lb. per day.

A suitable ration for suckling ewes and weaners is 55 parts of barley meal (or equivalent), 33 parts of middlings and 12 parts of fish meal (or equivalent). This later should be altered to 65 parts barley meal, 25 parts middlings and 10 parts fish meal. If the meal is mixed with separated milk instead of water, the fish meal may be reduced to 5 per cent. and the middlings put up by a similar amount. As the pigs grow older, it is advisable to reduce the amount of fish meal gradually to about 5 per cent., increasing the barley meal, or mixture of barley meal with other cereals, accordingly. In the final stages of fattening, fish meal may be omitted altogether, a procedure which eliminates risk of taint in the carcass, or, alternatively, it may be replaced by extracted soya bean meal.

Pigs intended for the butcher at 18 to 20 weeks, giving a carcass weight from 60 to 80 or 100 lb., should be pushed on as rapidly as possible, the best method being to keep them fat from birth. Such animals may be fed up to the limit of appetite, attention being paid to keeping the ration suitably balanced throughout the period of feeding. In the case of pigs being reared for the bacon factory, at 130 to 160 lb. carcass weight, the feeding should be such as to

TABLE XV.—DATA FOR COMPUTATION OF PIG RATIONS.

(*Taken from "Rations for Live Stock.*")

Live-weight lb.	Appetite lb. meal.	Maintenance lb. meal.	Requirement per lb. live-weight gain lb. meal.	Requirement of digestible protein lb.
50	2·0—2·5	1·5	0·7	0·3
100	4·0—4·5	2·9	1·0	0·5
150	16·0	3·3	1·5	0·6
200	6·9	3·6	2·0	0·6
250	7·5	3·8	3·0	0·7
300	8·0	4·1	3·5	0·7

allow the animals, in the earlier stages, to make rapid growth without becoming fat, the necessary fattening being produced in the month or six weeks preceding slaughter. Table XV. gives all the data required for the computation, for pigs at different live-weights, of rations designed to produce any desired rate of live-weight gain which is within the capacity of the animal. Allowance has been made in the maintenance rations for an average amount of muscular activity such as is compatible with good management.

(1) Wood, T. B. "Animal Nutrition." University Tutorial Press, Ltd.
(2) "Rations for Live Stock." *Miscellaneous Publication, No.* 32. Ministry of Agriculture and Fisheries.
(3) "Ensilage." *Bulletin No.* 37. Ministry of Agriculture and Fisheries.
(4) "Home-Grown Feeding Stuffs." *Bulletin No.* 13. Ministry of Agriculture and Fisheries.
(5) "Oil Cakes and Extracted Meals." *Bulletin No.* 11. Ministry of Agriculture and Fisheries.
(6) "The Feeding of Dairy Cows." *Bulletin No.* 42. Ministry of Agriculture and Fisheries.
(7) Wood, T. B., and Newman, L. F. "Beef Production in Great Britain." Silcock and Sons, Ltd.

CHAPTER XX.

THE HORSE: BREEDS AND MANAGEMENT.

In this chapter horses are dealt with strictly from the point of view of the farmer, and for this reason it deals mainly with heavy draught horses. At the same time a short account of some of the lighter breeds is given since these find a place on some farms.

The horse still remains an animal of considerable importance on the farm. The prophecy that for farm work horses would largely be replaced by tractors has not been fulfilled. Indeed the tractor has come to be recognized as a supplement to the horse rather than a substitute. It enables the farmer to push on with important work at critical times, and for this purpose is often extremely valuable, but it is only on the larger farms that it may be regarded as replacing a definite number of horses. On every farm there is much work that can only be economically performed by horses, and every farm, even the largest and best adapted to the use of mechanical power, requires a certain complement of horses.

That mechanical power has largely displaced the horse for road transport cannot be denied, but apart altogether from agriculture, the horse is still the most economical means of performing certain tasks. The horse may be described as a very flexible motor. It is capable of exerting tremendous power for a short time, hence for moving heavy loads short distances the horse still remains the most efficient source of power. Compared with pre-war days the demand for horses for town work is very much reduced (apart from cobs and horses required for milk floats and other vehicles of that kind), and is restricted to the heaviest draught animals. Provided the horse is sound and shows a reasonable amount of quality

and activity, the price the town buyer is prepared to pay is in direct proportion to its size. Unfortunately the price is no higher than it was in pre-war days and even at this price the demand is limited. It therefore follows that unless this particular type of horse is also the type best suited to the requirements of the farmer himself, the wisdom of its production is doubtful.

For ordinary farm work the type of horse most in favour to-day is an active, clean-legged one, showing plenty of quality but perhaps less weight than formerly. Though weight and size are always welcome (and for some land essential), it is maintained that from the farmer's point of view, such points as activity, hardiness, endurance, staunchness, longevity, and freedom from such complaints as "Grease," are of far greater importance, and that no amount of weight will compensate for their absence. As the majority of the heavy horses that are bred to-day begin and end their days at purely farm work, it is clear that the claims of the farmer should have pride of place in the type of horse which is to be produced.

The ideal heavy draught horse should be large, heavy, and powerful. The general impression should be one of massiveness. By large is meant from 16 to 18 hands high (the height is measured at the withers along a vertical line falling just behind the forelegs, and is expressed in hands, one hand being four inches), and weighing from 1,700 to 2,000 lb. or even over. When viewed from the front or rear, the body should appear broad or thick, and viewed from the side should give the impression of depth. If the depth through the chest is equal to the length of leg, then the animal will have that "low set" appearance which is so desirable, bringing the weight close to the ground, and enabling it to be used to the best advantage. The body should be well proportioned and substance should be combined with "quality."

Quality is indicated by the character of the bone, tendons, head, skin and hair.

The bone should be flat and smooth, hard and dense, the cannon-bone being usually taken as indicating the quality of bone of the rest of the skeleton. The joints should be clean and well defined.

The tendons, particularly those at the back of the cannon-bone should be well defined.

The head, which is taken as an indication of quality in all classes of stock, should show "breediness." In the heavy draught horse it will be larger in proportion to the body than in the lighter breeds. It should be "lean" and cleanly chiselled, with prominent, large and expressive eyes, and thin lips. A "fleshy" head indicates a soft body, and a small eye often indicates a mean and sulky disposition.

The skin should be mellow and elastic to the touch, covered with fine lustrous hair, and the "feather," which should not be excessive in quantity, should be fine and silky.

The feet of the heavy draught horse are of first importance,

hence the saying "no foot, no horse." They should be large, uniform in size, round and neither thin nor flat. The soles should be concave with a well-developed frog, the heels wide, and the slope of the hoof parallel with the pastern. The quality of the horn is important; it should be hard, tough and dense, smooth and free from seams or cracks.

The walk of the heavy horse is of prime importance, because it is at this gait that most of his work is done. The action should be free, that is the stride should be long and powerful, and above all straight, the limbs being moved forward in line. The trot is secondary to the walk, yet a horse which can trot well is generally a good walker. The trot should be strong and regular, all the joints being well flexed.

The disposition should be gentle with an absence of vice, yet not dull, slow, or indifferent. With the increasing cost of labour and the consequent increasing expense of breaking young horses it is a great advantage to have docile animals which may be broken and handled with a minimum of expense.

Breeds.—The breeds of horses recognized in this country are :—

Shire	Percheron	Hackney
Clydesdale	Thoroughbred	Cleveland
Suffolk		Pony

The Shire, Clydesdale, Suffolk and Percheron may be classed as heavy horses and the Thoroughbred, Hackney, Cleveland and Pony as light horses.

The Shire.—In the closing years of the 18th century, Arthur Young, describing his agricultural tour, made reference to the large black old English horse, "the produce principally of the Shire counties in the heart of England." Long previous to this, however, the word "Shire," in connection with horses, was used in the statutes of Henry VII. Under the various names of the War Horse, the Great Horse, the Old English Black Horse, and the Shire Horse, the breed has for centuries been cultivated in the rich fen-lands of Lincolnshire and Cambridgeshire, and in many counties to the West. It has been developed from the original horses of this country, which were famous as far back as the Roman invasion, and improved by the use of stallions imported from the Low Countries.

The Shire is the largest and heaviest breed of horse in the world, the stallion commonly attaining a height of 17 hands or more. Though the black colour is still met with, bay and brown are now more usually seen. The lighter colours such as chestnut, roan and grey are not so popular. With his immense size and weight—1,800 to 2,000 lb.—the Shire combines strength and docility. His legs should be as massive as possible so long as the bone is clean and flat. The bone should measure not less than 11 in. in circumference below the knee and 12 in. or more below the hock.

A characteristic of the breed is the quantity of hair or "feather" carried below the knee and the hock, not merely at the back of the legs but also at the sides. Great attention is paid to the character of this feather, which is taken as indicating the quality of the bone; it should be long, fine and silky, not wiry nor woolly, and be free from any tendency to curl. That this feather gives the animal a most attractive appearance in the show ring—emphasizing the general massiveness of the horse is indisputable, but the utility of such a mass of hair upon sticky clay land, particularly in these days of expensive labour, is, to say the least of it, doubtful. *That the fetish of feather has been carried to excess in the past is reflected in the relatively higher prices which farmers are willing to pay for the cleaner legged type as compared with those carrying enormous* quantities of hair.

"Keep the lorry in view" is a well known slogan amongst the breeders, and with this motto ever blazoned before their eyes they have evolved weight. "Weight" means "Avoirdupois" for weight moves weight.

The Shire Horse Society aims to-day at breeding horses which when mature approach to the following description :—

"17 hands high, alert, with head majestically carried on muscular, slightly arched neck; sloping shoulders; strong, short back, with well sprung ribs and long quarters; girth large, with plenty of thoracic accommodation for heart and lungs; chest broad and middle deep; legs well set under the body, arms and thighs long and muscular; knees flat and deep, hocks broad in front, deep behind, strong and clean; cannon-bones short, strong in front of the leg; clean cut sinews, well defined and flat behind the leg; pasterns strong and sloping but not too long; feet large, solid and deep, with strong quarters, clean coronets, and set straight without twist; hair straight and silky; movement level all round, straight and true with boldness of carriage, soundness in wind, limb and eyesight." (Plate II., 1).

Weight pulling competitions have been recently introduced into the London Shire Horse Show. Three official tests resulted as follows :—

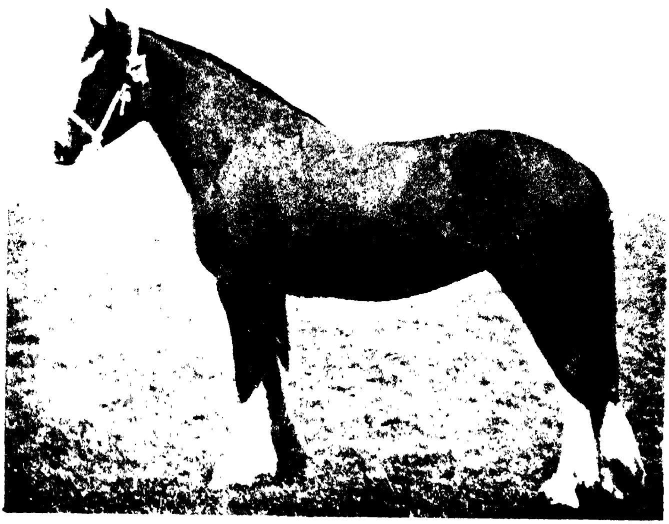
A pair of Shire geldings pulled a load of 18½ tons on granite setts, 16½ tons on wood blocks, and 6 tons on the tan in the ring. The two horses were in tandem formation yoked to a 2½-ton dock lorry.

CLYDESDALE.—The Clydesdale is the heavy draught breed of Scotland. It is somewhat smaller than the Shire, the average height of stallions being about 16½ hands, and is distinctly lighter. It is not so well ribbed up as the Shire, nor so deep, the legs being considerably longer. It is, however, very active, with straighter action, and much less feather, there being only a fringe of fine silky hair confined to the back of the leg. (Plate II., 2).

"The breed is famous among draught horses for activity; cleanness and soundness of bone; freedom and general perfection

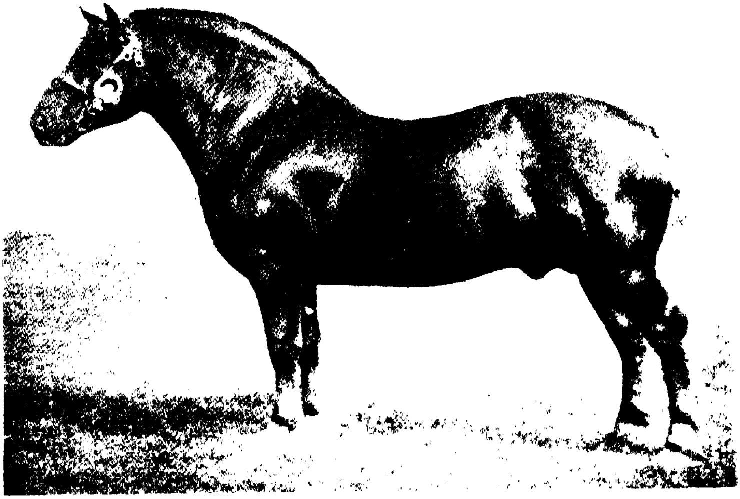
PLATE II.

1. SHIRE FILLY.

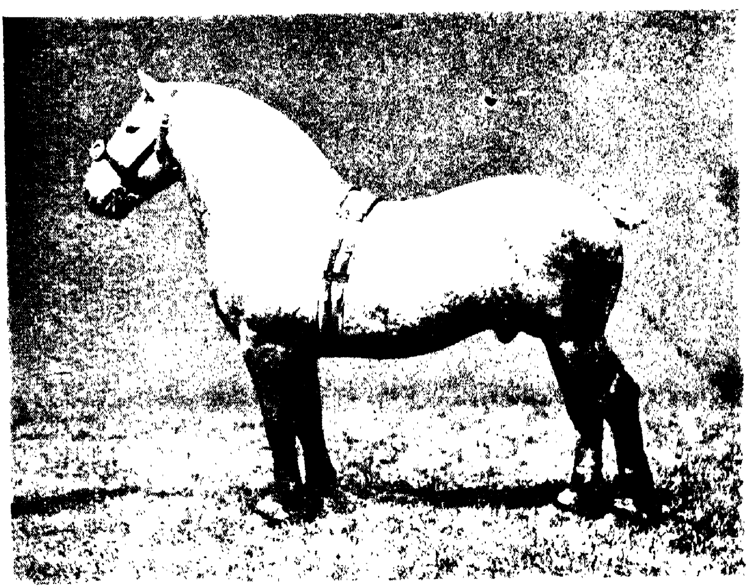


2. CLYDESDALE FILLY.

PLATE II. *continued.*



3. SUFFOLK STALLION



of knee and hock action at the walk and in the trot ; length and slope of pastern, size and openness of feet ; gaity of carriage ; fineness of skin ; silkiness, straightness and length of feather, which is confined to the back of the leg and does not spread to the side ; general beauty and symmetry, though there is a tendency in some members of the breed to shortness in the back ribs and consequent lightness in the barrel ; good sloping shoulders and short muscular loins and back.

In action the hocks should move closely together, and the hind toes turn slightly outwards, but not sufficiently to throw out the stifle joint. Wideness at the hocks, more common with stallions than mares, implies weakness of the loins, and tends to grow worse with age. The joints of the limbs should be large and clear, and the large round feet substantial, smooth, shortened at the toes, and well arched below without any trace of thinness or flatness."

SUFFOLK.—Whilst the Shire and the Clydesdale present many points in common, the Suffolk is quite distinct from either. At the present day it approaches the Shire or Clydesdale in height, but is distinguished by its chestnut colour and an absence of feather on the leg. (Plate II., 3.)

Short legs without hair, and deep thick body, coupled with the wonderful natural condition which the horse always carries, give rise to its popular name of " Suffolk Punch." To those accustomed to other breeds the Suffolk looks too heavy for its legs, but actual measurement shows that it is in no way deficient in bone.

In the Great War, the Suffolk won golden opinions for its staunchness in the collar and for its ability to thrive under the worst conditions. The reputation there won, combined with the modern demand for clean-legged cart horses, has been reflected by a greatly increased interest in the breed.

The breed is justly famous for its hardiness, longevity, docility, gameness, and willingness to work. These valuable characteristics combined with handiness and quickness in turning, make the Suffolk an ideal agricultural horse. At the dead pull the horse has no equal, and it was formerly the custom to have " draw matches " associated with local shows.

In the past the Suffolk has not been popular with town buyers owing to defective feet ; these were inclined to be pinched at the heels, and gained slope at the expense of being shallow over the bars. Moreover the horn itself was of poor quality. Much attention has been paid to the feet in recent years with good results, and there is now quite a keen demand for geldings of the breed for town work.

THE PERCHERON.—This breed of heavy draught horse is a native of France, and is a comparative new-comer into this country, where its merits are rapidly being recognized. During the Great War, thousands of pure-bred and half-bred Percherons were purchased from Canada and America (where the Percherons outnumber all

other heavy breeds) for Army Transport work. They were so markedly successful that attention was drawn to their great value for the agricultural industry in this country, where clean-legged cart horses were rapidly coming into favour. This led to the formation of the British Percheron Horse Society in 1918 and the importation of specially selected pure-bred mares and stallions from the La Perche district of France. (Plate II., 4).

The Percheron is one of the most active of draught breeds and compares with the Suffolk for hardiness, longevity, and thriftiness. The colour should be grey or black, though bays and chestnuts occur. It is medium in size, though many individuals attain great scale, and the tendency in this country is to breed the heaviest type. The head is breedy in character, and the prominent eyes and sometimes dished face suggest Arab blood, which was, in fact, introduced many years ago. The neck is long and powerful, the back broad and well carried. The croup though wide is often steep, and this to English eyes, gives the horse an odd and unpleasing appearance. Unfortunately, too, the steep croup is often associated with a "crooked" hind leg. The legs are strong of bone and free from hair, and the feet are of excellent size and texture.

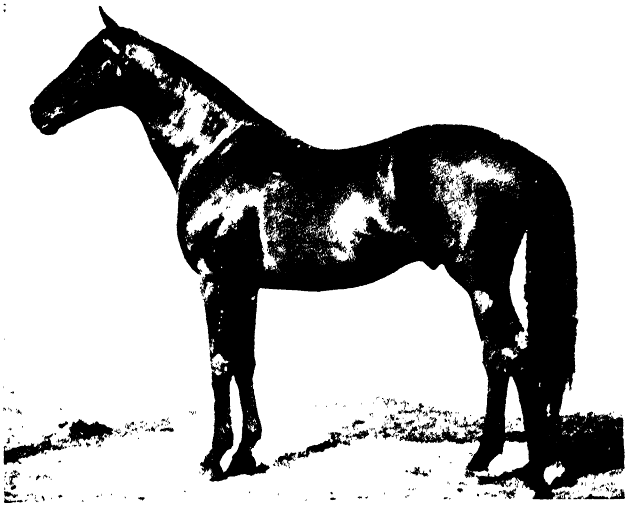
Though it is not difficult to criticize the Percheron horse, the fact remains that it can justly claim to be the heavy draught horse of the world, and this in spite of the fact that such countries as America and Canada started with a prejudice in favour of some of our English breeds. The Percheron must have won his present position on his merits alone, a fact which should give British heavy horse breeders food for thought. A valuable export trade of Percheron stallions exists from France to the United States and Canada and in addition South America, Africa, Australia, and Japan are all buying Percherons.

In the hands of Englishmen, who as a race have always been famous as breeders and horse-masters, it would seem that the breed has great possibilities and part at least of the export market may be captured.

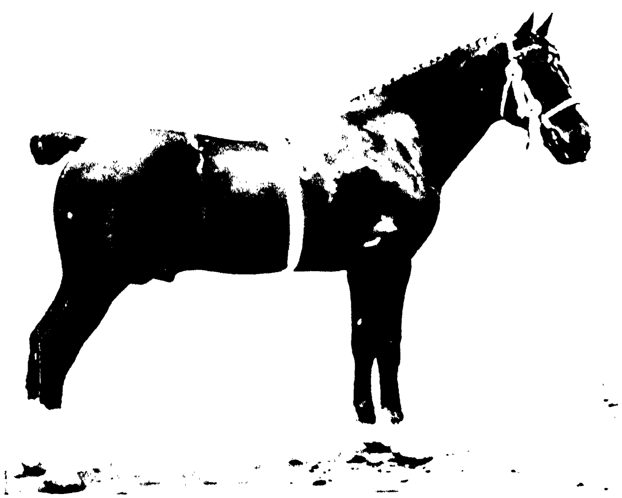
THOROUGHBRED.—The Thoroughbred is of interest to the farmer mainly as providing the material for the breeding of Hunters. On no breed of animal has greater thought, care, or money been bestowed. It has been bred without admixture of alien blood for over 150 years. The improvement has been great in the special direction and for the special purpose for which the race-horse is kept. Two distinguishing qualities of the British Thoroughbred are, great speed with a light weight over a short distance, and early maturity. For these results the modern short distance race and the racing of two-year-olds are responsible.

A scheme of Service Premiums for Thoroughbred stallions to serve the mares of farmers is maintained by the War Office, in order that a supply of horses suitable for cavalry remounts may be obtained. Sixty King's Premiums are annually awarded, with twelve super Premiums for stallions of exceptional merit. These

PLATE III.



1 Thoroughbred Stallion



2 Hackney Stallion

stallions are available at nominal fees and are used by many farmers to suitable mares with a view to breeding hunters.

A thoroughbred stallion should be about 16 hands in height, with oblique shoulders, fine withers, a long muscular neck joining on to deep shoulders, a lean masculine head (broad between the eyes, with the latter well developed), short and deep back, barrel well ribbed up, and well sprung ribs; with muscular quarters and loins, flat cannon-bone (which should be short) and well formed big knees and hocks. The feet should be open at the heels and not too large. The pasterns should not be too long or too straight. (Plate III. 1).

THE HUNTER is a type of horse rather than a breed. Some are pure thoroughbreds, others are the progeny of thoroughbred stallions mated with suitable mares, *e.g.*, Cleveland Bays. A considerable proportion of thoroughbred blood in the dam, however, is desirable, and gives a larger proportion of offspring suited to hunting.

The most valuable hunter is a horse which is up to weight, half-a-dozen good light-weight hunters being produced for every heavy-weight. He must possess exceptional powers of endurance, speed and jumping, good manners and good looks. Such a horse, if sound, is at six years old a very valuable animal. Indeed these heavy-weight hunters were never more expensive, nor more difficult to find than they are to-day. That the high price and keen demand has not increased the supply is accounted for by the fact that the outlet for the "misfit" hunters (*i.e.*, horses bred with a view to their being hunters, but which fail in some respect), is very limited. Before the days of motor cars these misfits were readily saleable for tradesmens' carts, carriages, etc. To-day the only outlet is the Army Remount Department, which requires but a limited number annually.

Whether hunter breeding is profitable for a farmer depends first of all on whether or not he lives in a hunting country and is a sufficiently capable horseman himself to be able to "make" young hunters. It is only for the finished article that the high price can be made. It also depends on what work is available for the mare. Where a single brood mare may be a profitable side line, half-a-dozen may prove unremunerative.

THE CLEVELAND BAY.—This breed may be described as a general utility horse and comes midway between the heavy and light breeds. It is the oldest type of clean-legged farm horse and has existed in the North and East Ridings of Yorkshire for more than 200 years. There is no better base or foundation for crossing to obtain hunters, cavalry horses, and harness horses. The favourite cross is with the Thoroughbred stallion, and it is the only breed which can be crossed with "blood" and give added bone, strength, stamina and action, without at the same time seriously detracting from appearance, quality, and activity. Owing to the prepotency of the pure-bred Cleveland the stallions have been

extensively used in the Dominions and in North and South America. (Plate III., 3).

HACKNEY.—The breeding of Hackneys was once extensively pursued in the counties of Norfolk, Cambridge, Huntingdon, Lincoln and York. Originally the Hackney was a ride and drive horse. The pure-bred Hackney was mainly descended from a stallion foaled about 1755 and variously known as the Schales, Shields or Shales horse. The advent of the motor car, however, sounded the death knell of this once famous breed. No Hackneys are now bred for commercial purposes and the few that survive are bred purely for the show ring. These are shown as harness horses and the aim is an animal of extravagant action, quite unsuited for commercial purposes. Plate III., 2).

PONY.—The native breeds of pony include :—

Dales	Exmoor	Shetland
Fell	New Forest	Highland
Dartmoor	Welsh	

Ponies range in height from 14 hands down to $8\frac{1}{2}$ hands.

The various breeds mentioned above, differ considerably in size and appearance, but have certain characteristics in common and are probably of common origin, their distinctive features being the result of different conditions of environment and the varying nature of the work required of them. The rough conditions under which they have been bred for so many generations has resulted in the survival only of the fittest, hence all ponies are extremely hardy, are able to withstand severe climatic conditions, and to thrive on inferior food. In addition, they are amazingly strong for their size, active and sure footed.

Ponies are still required for certain classes of work though the demand is limited.

THE FEEDING AND MANAGEMENT OF WORKING HORSES.—The farmer may regard his horses in one of two ways. He may regard them simply as a means of performing certain tasks, in which case his object is to get these tasks performed in the cheapest way possible, or he may regard his horses, not only as a means of performing certain work, but also as a definite profit-earning department of his farm. Whichever view he takes he may set about achieving his object in a variety of ways. Thus in the first place the usual plan is to keep a regular team of working horses of all ages, making good the wastage which is continually going on through age, accident, and disease, either by purchasing young horses, or breeding a sufficient number of foals each year to meet the farm's requirements. In this way the buying and selling of horses is reduced to a minimum and every horse is retained in the team for the maximum period.

Some farmers, and particularly those with little capital available, will take the view that only old or unsound horses should be used for land work. Horses which, while quite unfit for road work, will work well on the land, may be purchased at very low prices.

In this way the capital locked up in working horses is reduced to a minimum, and though the wastage is bound to be high in such a team, yet it is possible that under certain circumstances a farmer may legitimately adopt this policy.

The farmer who has a taste for horses, and is a good judge of horseflesh (and in spite of popular ideas to the contrary, such a man is exceptional) may definitely manage his horses with the idea of turning his knowledge to profit. Such a man may, if he has a taste for the business, actually deal in horses. In this case he needs to be a good judge of a horse "in the rough" (a very different thing from judging a horse as presented in a show ring). Such a man will be continually buying and selling and no horse will remain in his teams for very long.

The horse that is in demand to-day, and that will command the highest price, is a five or six year old gelding, standing 17 hands high, weighing as near a ton as possible, sound, active, showing plenty of quality, and with not too much hair on his legs. This then is the animal which the farmer who is trying to manage his horses as a source of profit should aim to produce. He may produce it by breeding for himself, or by buying foals, yearlings, or two-year-olds. These animals he breaks and works in his team until they are of town age, when they are sold, and their places taken by the youngsters which are coming on.

The Feeding and Management of the Mature Horse must be determined strictly in accordance with the objects for which he is kept. Whether used for riding or driving, for purposes of draught, in towns, or on farms, the horse is a working animal. Consequently the horse requires a liberal supply of digestible carbohydrates in his diet. It is generally accepted that work is done at the expense of the non-nitrogenous constituents of the body—the carbohydrates and fats—which, as they are exhausted, are replaced by the carbohydrates and fats of the diet, and that protein is only decomposed for the production of energy for muscular work when carbohydrates and fats are not available.

The basis of a winter ration for a farm horse doing medium work may be taken as—

Oats 12 lb. per day—84 lb. (2 bushels) per week.
Hay 16 lb. per day—112 lb. (1 cwt.) per week.

In practice a certain amount of the hay is frequently displaced by straw, which is usually fed as chaff, and in some of the northern counties the farm horses are fed on oat straw and oats alone, without the addition of hay. Oat straw grown in these localities (generally particular varieties suitable for their climatic conditions), is, however, of far higher nutritive value than the oat straw produced in the south and east of England.

For horses doing fast work, *e.g.*, hunters, oats are essential, but for horses doing slow heavy work they can often be economically displaced by other forms of concentrated food, such as a mixture

of maize meal, bran, and beans. The quantity of "corn" given at any season should be regulated by the amount of work to be performed, and every increase in work should be met with an increase in the quantity of corn. The converse is not less important, for nothing is calculated to cause trouble more quickly than to feed a full corn ration to an idle horse. Spring and autumn are two busy periods, and farm horses, as a rule, should receive a more liberal ration at these times. Thus the oats might be increased from 12 to 14 lb. per day, with 2 lb. of split beans in addition. This is to be preferred to making the increase simply in the form of additional oats.

A horse has not the capacious stomach of an ox, neither has it the power of ruminating its food. For these reasons it is necessary that horses should have their food in a more concentrated form. All corn is best given crushed or bruised along with hay or straw chaff, so as to prevent bolting and to ensure mastication. A horse should not be groomed while he is feeding. A moderate allowance of roots or other green foods as they come in season, should be given. A lump of rock salt should always be kept either in the manger or in some other convenient place where the animals may have access to it. Regularity of feeding should be practised, moderate meals at fairly short intervals being, on account of the nature and duties of the horse, preferable to heavier meals at longer intervals. An abundant supply of pure water should always be available.

The stable should be commodious, freely ventilated, light, well drained and free from draughts. It is important that stable drains should be on the surface, and should empty into traps outside the stable. Horses incur more risk of ill health in badly constructed stables than they do in the field. In the east of England it is the custom to keep the horses in semi-covered straw yards at night, the stable being used only for feeding the concentrated part of the ration, for grooming, and for putting the harness on the horses. Under this system much labour is economised, and the horses thrive well, suffer less from colds and chills than they do if they are left in the stable all night.

During the summer months horses may be turned out to grass at night, or they may be kept in straw yards and cut green stuff carted to them. If the horses are doing a lot of heavy work, such as on the binder, the latter is to be preferred, but when horse work is slack, as is often the case during considerable periods of the summer, it is probably more economical to turn the horses out to grass. Unfortunately the horse is a thoroughly bad grazer, the dung being always dropped on selected spots in the field, the coarse herbage resulting being discarded. This gives rise to the characteristic patchy appearance of pastures grazed entirely by horses, and pastures should not therefore be stocked by horses exclusively. During the summer the corn ration may be reduced.

Cost of Horse Labour.—As the basis of all charges for tillage operations depends on the cost of horse labour it will be worth while

to make an estimate of the actual cost to the farmer of keeping a working horse for a year.

The question of feeding must first of all be considered, and it will be found that the rations suggested below approximate very closely to those used on many well managed farms throughout the country.

COST OF FEEDING.

Winter—say 32 weeks, October—May.

		s.	d.
2 bushels of oats per week at 3*s*. 6*d*.		7	0
1 cwt. of hay per week at 3*s*.		3	0
1 cwt. of straw per week at 1*s*. (for chaff and litter)		1	0
Extras (linseed, bran, and a few roots)		0	6
Cost of feeding for 1 week in winter		11	6
Hence cost of feeding for 32 winter weeks	£18	8	0

Summer—say 20 weeks, May—September.

		s.	d.
1 bushel of oats at 3*s*. 9*d*.		3	9
Grazing at 2*s*. 6*d*.		2	6
Cut fodder, say		1	6
Cost of feeding for 1 week in summer		7	9
Hence cost of feeding for 20 summer weeks	£7	15	0
Total cost of food for 12 months	£26	3	0

The other items connected with keeping a farm horse may be estimated as follows :—

COST OF KEEPING A FARM HORSE FOR A YEAR.

	£	s.	d.
Food	26	3	0
Shoeing and stable requisites	2	15	0
Depreciation and repairs to harness	2	5	0
Depreciation on value of horses, 10 per cent on £40 ...	4	0	0
Labour	4	10	0
Incidentals, including Veterinary attendance, and medicine, say	0	15	0
	£40	8	0

In making the above estimate nothing has been allowed for depreciation and repairs to the farm implements, an item which is generally included when estimating the cost of horse labour. This item is frequently a very heavy one and may easily amount to from £8 to £10 per horse.

If we include this item we may say that a farm horse costs roughly £50 a year.

According to the class of soil, the type of cultivation practised, and the particular weather in any given season, the total number of days upon which the horse will work will vary from 180 to 220. Taking the average as 200 it appears that at the prices quoted above the cost of horse labour would be 5*s*. per day.

The amount allowed for depreciation on the original value of the horse in the above calculation may in some cases appear too high. Where the team is managed on some of the lines already indicated depreciation may be converted into appreciation, in

which case the cost of horse labour to the farmer is considerably reduced.

Heavy Horse Breeding.—*With an ample supply of cheap horses there is little incentive for the farmer to breed. There are indications, however, that the present state of things will not continue* indefinitely, for the number of horses that have been bred in the last few years, as indicated by the returns of the Ministry of Agriculture, is insufficient to replace the normal wastage in agricultural horses alone, without counting the large number that is still used for town work. Unless more horses are bred it seems likely that horses for purely farm work will become dearer, in which case heavy horse breeding should once again be a profitable side line.

Selection of Stallion.—The stallion should be big and massive, about 17 hands high, with big knees and hocks and the best of feet. He must be a good walker and able to trot with dash. A horse that goes wide in the hocks, or throws his fore legs about should be avoided. He must, of course, be sound, and made like a weight-carrying hunter. A stallion with good limbs, though lacking in the barrel, is much to be preferred to a big bodied horse with round defective limbs and moderate feet. It usually pays to use the best stallion available even if he does cost an extra guinea. At two years old a stallion may be used to serve a few mares, though at this age they are uncertain stock getters. A stallion which fails to leave foals at this age may be perfectly satisfactory as a three-year-old.

Selection of Mare.—One good brood mare is more profitable than a number of ordinary ones. She should be long, low, and wide, sound and free from grease. Tall "split up" mares are not good brood mares, neither are light-ribbed "pretty" mares.

There is little to be gained by starting the season too early; few mares get in foal before May. A mare which has foaled is more likely to stand to service on the ninth day after foaling than at any other time. A mare comes in season at three-weekly intervals during the spring and summer, and will remain on heat 5, 7 or even 10 days. Fillies which are well grown may safely be mated at two years of age provided they are well done and are not worked during pregnancy. It is preferable, however, to wait until they are three.

Up to the fifth or sixth month of pregnancy no differentiation is made in the treatment of an in-foal mare. Subsequently she will be put in charge of a careful man when at work and will be worked only in chains. She may be worked regularly with advantage up to the time she is due to foal. Her food will be improved, hay being substituted for straw in her ration, and her allowance of oats and bran slightly increased. At the same time it is a great mistake to allow the mare to become too fat. Mares regularly worked rarely have much trouble in foaling, whereas the risk with fat and idle mares is considerable. The gestation period is about 340 days. The fecundity of horses is rather low. If calculated over a period

of years not more than sixty per cent. of served mares prove in foal.

Mares should be foaled down in a clean and well disinfected loose box. The bowels should be kept well open by feeding sloppy foods. Immediately after birth the naval cord of the foal should be tied up and disinfected. This disinfection should be repeated until the naval has dried up. A great cause of mortality in foals is constipation soon after birth. The symptoms are switching of the tail, straddling and general uneasiness. The rectum should be cleaned and a soap and water enema injected. A wineglass full of castor oil should also be administered.

The mare and foal are turned out to grass as soon as the weather is suitable, and the foal continues to suckle for four, five, or six months. Towards the end of this period some crushed oats and bran are fed to the mare for a couple of weeks before the foal is weaned. In this way the foal learns to eat the corn. When the foal is weaned it should be pastured in a field not previously grazed that season by horses, or better, given the run of a new seeds ley. Here it will receive about 4 lb. a day of a mixture of crushed oats and bran in equal parts.

A foal will thrive best in company with other foals. It should be accustomed to the halter before it is weaned, and if led every day for a week in early life will never afterwards forget it. In this way breaking-in is facilitated.

It is during their first winter that horses are made or marred. If starved at this period they will never make the animals they would otherwise have done. On the other hand if well done in the first winter they may subsequently be treated rather roughly without suffering permanent damage.

In winter the young animals are sometimes housed, but have access to large airy yards, as exercise is absolutely essential to their healthy development. Most breeders, however, prefer to let the foal run out all winter in some sheltered paddock, with open sheds available for bad weather, and for feeding. Regular feeding with oats, beans, bran, and plenty of good hay during the first winter is essential. During this time, particularly if the animals are in yards, their feet should be watched and kept pared into shape. The colts are as a rule castrated at 12 months old.

The following summer the young colts will spend at grass. It is undesirable that they should be allowed to get too fat, consequently second-class pasture, well watered, and free from pitfalls, is indicated. From now onwards they are little trouble and will spend the rest of their time on the pastures, helped with hay during the winter, until wanted for work.

Breaking-in to Work.—At the age of two or three years, the age depending upon the type of soil on which the farm is situated and the forwardness or otherwise of the young horses, the colts will be broken to regular farm work. They are very little trouble as a rule, particularly if they have been taught to

lead as foals. In the first place they are harnessed to a log of wood and allowed to drag it about.

Within a few days they may be put in the plough between two steady old horses. Young horses should not be overworked; half a day at a time at first is quite sufficient, nor is it wise to do much carting with a young horse or to work it on hard roads until it is between four and five years of age.

CHAPTER XXI.

CATTLE : BREEDS, TYPES, MANAGEMENT AND BREEDING.

THE various breeds of cattle may be classified either as beef, dual-purpose or dairy breeds.

The function of the beef type is the production of beef animals pure and simple. The cow is expected to produce a calf each year, usually in the early spring. While being pastured during the summer on moderate grassland, she is expected to provide sufficient milk to rear the calf well, so that in the autumn, when it will be weaned, the farmer may be left with a first-class young feeding beast. The cow must, in addition, be hardy and able to maintain herself cheaply. The total output per cow being comparatively small, *i.e.*, one weaned calf per annum, it follows that if a profit is to be made the total cost of maintaining the cow for a year must be correspondingly low.

It is impossible that the greatest degree of excellence in both beef and milk production should be combined in one animal, but several British breeds combine the two characters to some extent. This type of dual-purpose animal is peculiar to this country and has been evolved as one which suits our particular conditions. The ideal dual-purpose type of cow is one that will give a good account of herself at the pail, *i.e.*, 800 to 1,000 gallons per annum at maturity, whose bull calves may be profitably reared to make either first-class beeflings or good mature beef, and who, when her milking days are over, will herself readily put on flesh and make a first-class carcass of cow beef. Such a cow must, in addition, be a regular breeder, and her heifer calves should be capable of reproducing her own performance.

The dairy breeds are milk producers only. The high yields of milk obtained at the present day demand not only a first-class milker but an animal of good constitution and large capacity for feed. The bull calves from this type of animal are not as a rule profitable to rear and are best dealt with as veal. The cows, being naturally thin-fleshed and of dairy conformation, do not themselves feed into good carcasses. If we take into consideration the great wastage that undoubtedly occurs among these very deep milking cattle, it will be seen that their low value as beef is a point of considerable importance. The pure dairy and beef breeds may, however, be

PLATE IV.

1. Shorthorn Cow.

2. Dairy Shorthorn Cow.

PLATE IV. *continued.*

3. Hereford Cow and Calf.

4. Aberdeen-Angus Cow.

relied upon to breed true to type with far greater certainty than is the case with the dual-purpose breeds.

It is not easy in all cases to classify the breeds exactly as belonging to one of the three types mentioned above as different strains of the same breed may vary.

The following classification is, however, usually accepted :—

Beef Cattle.

Shorthorn	Sussex
Hereford	West Highland
Aberdeen Angus	Galloway
Devon	Lincoln Red Shorthorn (some strains)
	Red Poll (some strains)

Dual Purpose Cattle.

Dairy Shorthorn	Lincoln Red Shorthorn
Red Poll	South Devon
Welsh Black	Dexter

Dairy Cattle.

Ayrshire	Jersey
Guernsey	British Friesian
Kerry	

BEEF CATTLE.

THE SHORTHORN.—This is the most widely distributed of all breeds of cattle both at home and abroad. Cattle of Shorthorn type dominate the markets in the United Kingdom with but few exceptions. Its origin is lost in antiquity but it was brought into prominence during the last quarter of the 18th century by the exertions of the brothers Charles and Robert Colling, of Barnston, near Darlington. These two young men, at the instigation of their friend Culley who had been a pupil of the famous Bakewell, visited him in the year 1783 in order to study his methods. Bakewell's improved Leicester sheep was then becoming famous, and he had started to work on similar lines with Longhorn cattle. It was in fact to distinguish the cattle from this breed that the name Shorthorn arose. The brothers Colling returned home with the determination to apply Bakewell's methods of improvement to the cattle of their home district, the Teeswater district of the county of Durham, and the cattle evolved from this foundation stock are still termed Durhams in many parts of the world.

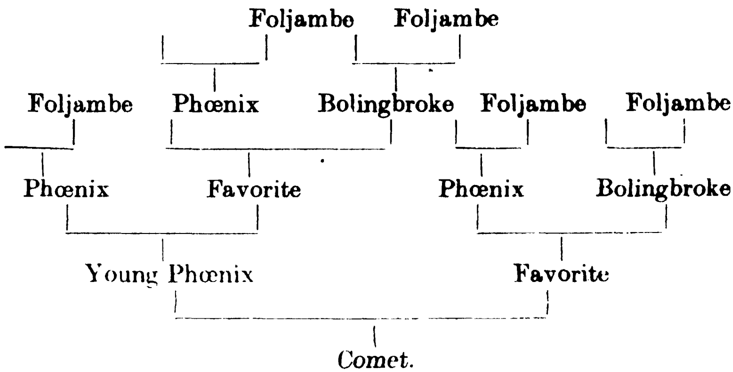
The cattle with which the brothers Colling started to breed were large, coarse, flat-sided and leggy. They were covered with scanty, coarse hair and were thin-fleshed, but the cows when dried off had the power of putting on flesh in the form of large quantities of patchy fat. They were slow growing cattle of all colours, not excluding black, and the cows were good milkers. In origin, the Shorthorns were undoubtedly dual-purpose in character.

Collings' work resulted in an animal of moderate size, symmetrical, and early maturing, with well-sprung ribs, short legs and good thick hide covered with thick, mossy hair. The cattle were thick-fleshed but there still remained a distinct tendency towards patchiness. As regards dairy qualities it is probable that

these had been impaired, the greatest advance having been in the direction of early maturity.

The method of breeding employed was Bakewell's policy of rigorous selection and very close in-and-in breeding to fix the desired type. As an example of this method the pedigree of the famous bull Comet may be cited. Comet was sold in the year 1810 by Charles Colling, then in the height of his fame, for the previously unheard of sum of 1,000 guineas. His breeding was as follows :—

The bull Bolingbroke and the cow Phœnix (half-brother and half-sister, both being by Foljambe) were mated together and produced the bull Favorite. Favorite was mated to his own dam Phœnix and produced a heifer Young Phoenix. Favorite and Young Phœnix were mated and produced Comet.



The pedigree has been summed up as :—by Favorite, dam by Favorite out of Favorite's dam.

The Collings were followed by other shrewd breeders who established famous strains and families : of such breeders the best known are Thomas Booth of Warlaby and Killerby in Yorkshire, who originated the "Booth" strains of Shorthorns ; Thomas Bates of Kirklevington in Yorkshire, by whom the "Bates" families were established. Booth concentrated on a beef type, while Bates' cattle were dual-purpose, and these characteristics of the two strains, in the main, still hold good to-day. In later years came Amos Cruikshank of Sittyton, Aberdeenshire, the originator of the famous Scotch families of beef Shorthorns.

The popularity of the Shorthorn arises from its unrivalled range of adaptability, thriving as it does in most countries and climates. It is famous for its great prepotency, *i.e.*, the power of transmitting to others its own good qualities, and it is famous for improving and grading up "native" or scrub cattle of all kinds. For crossing purposes, therefore, the breed is unrivalled. The use of Shorthorn bulls on native cattle has been followed by improvement in size, form, quality, rapidity of growth, and aptitude to fatten at an early age.

At the present time there are two very distinct types of Shorthorn, though both types are of common origin and both are included in the same herd book. One type, the dairy Shorthorn, is a dual-purpose animal which will be dealt with under that heading, and the other the beef Shorthorn, sometimes called the Scotch Shorthorn. This is a beef breed pure and simple, and one of the few criticisms that may be levelled against it as such is that in some strains the cows are such poor milkers that they hardly give enough milk to rear their own calves.

Red, white and roan are the characteristic colours of the breed, which is distinguished by its symmetrical proportions and by its great bulk on a comparatively small frame. The head of the male is somewhat short, broad across the forehead, but gradually tapering to the nose; it should show strength and masculine character; the nostril full and prominent; the muzzle, palate and lips flesh-coloured, with a complete absence of pigmentation. The horns should be short, flattened laterally, waxy in texture, slightly curved in a forward direction, blunt and free from black at the tips. The head is well set into a broad muscular neck, the chest wide, deep and projecting; forelegs short and wide apart, body round, deep and well ribbed up towards the loin and hips which should be wide and level; back straight from the shoulders to the setting of the tail; the hind quarters lengthy, but well filled up; the hair plentiful, soft and mossy, with a hide not too thin, and having a fine and mellow touch. (Plate IV., 1 and 2.)

THE HEREFORD.—*The cattle of this breed are typical of* Herefordshire and the adjoining counties. They are essentially a grass beef breed, being good grazers and fattening readily on grass alone, even on pastures which are not quite first-class. Their long horns do not make them popular for fattening in yards, though polled Herefords sell readily for this purpose.

Hereford cattle are bred and reared under natural conditions, the cows running out in the pastures all the year round, receiving hay and straw during severe weather and at calving time. Many breeders even allow them to calve down in the open. The result of this treatment is that the breed is practically free from tuberculosis. The cows are good mothers, rearing their calves well. " Herefords have proved themselves to be one of the best breeds for ranching purposes. In countries where droughts are prevalent, water and fodder short and difficult to obtain, and where long distances have to be covered, Herefords will often thrive where other cattle die."

They are rather deceptive in appearance, looking bigger and heavier than they really are, and this has earned for them the nickname among butchers of " the white-faced robber." Grass-fed Herefords are in great favour on the London markets. The hide is heavy and of first-class quality, being particularly thick and elastic. (Plate IV., 3.)

THE ABERDEEN ANGUS.—This black, hornless breed is native to the north-eastern counties of Scotland, where it can be traced

back as early as the first quarter of the 16th century. At the present time it is found in almost every Scotch county and there are also many herds in England and Ireland. Outstanding names as improvers of the breed are those of Hugh Watson, Keiller, Forfarshire (1808-60), William McCombie, of Tillyfiur, and Sir G. M. Grant, Bart., of Ballindalloch, Banffshire.

As a carcass of beef the Aberdeen Angus is very nearly perfect. The finished beast is remarkably blocky, very level fleshed, and is a solid mass of firm meat. The proportion of dead to live weight is unusually high and this breed holds the record with a yield of $76\frac{3}{4}$ per cent. The bone is light and the carcass is particularly good in the high proportion of its first-quality joints. The breed is early maturing and produced the first two-year-old champion at the Smithfield Fat Show. The only drawback to these cattle is the fact that they are inclined to be rather wild, particularly if not treated quietly.

The bulls of the breed are extensively used for crossing for the production of quick maturing high-class steers, though when mated to thin-fleshed dairy type cows the result is often disappointing. The calves are rather small at birth, and are slow growers for the first six months. (Plate IV., 4.)

THE DEVON.—The Devon or North Devon as it is frequently called to distinguish it from the South Devon, is another beef breed of the highest quality. The cattle of this breed are rather small in size and a rich ruby red in colour. They are characterized by their extreme neatness, fineness of bone, and evenness of fleshing. For its size the animal is remarkably thick-fleshed and is very popular with butchers in markets where it is known In spite of its high quality as a beef breed, but few herds are kept exclusively for beef production, a certain amount of milk being drawn during the spring and summer, from which is made the famous Devonshire clotted cream.

The Devon turns to the best advantage the short sweet pastures of its native county, and fattens readily on pastures which would not be suitable for larger cattle. (Plate V., 1.)

SUSSEX.—This breed of medium to large beef cattle were, 100 years ago, essentially a draught breed. It takes its name from its native county, and is still in great favour on the Wealden clays and the marshlands of Sussex, Kent and Surrey. It is one of the hardiest breeds, able to thrive and do well under the most unfavourable circumstances as regards food, soil and climate. It will keep itself as a good store on the poorest pasture. As a grazer it is remarkable for the fact that, unlike most cattle, it does not pick and choose, but will graze right through a pasture, from one side to the other, taking the rough with the smooth.

Sussex cattle are good as regards early maturity and particularly good if well done, making first-class beeflings. When well finished they make excellent beef. The cattle being very hardy, the cows are frequently left out all the year round. It is claimed that three

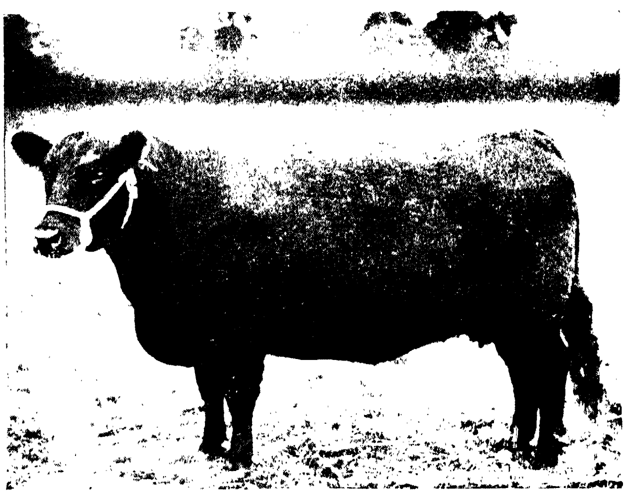
PLATE V.

1. North Devon Cow.

2. Sussex Cow.

PLATE V. *continued.*

3. Highland Cow.



4. Galloway Cow.

acres of poor Wealden clay pasture will provide food for one cow for 12 months. The calves are dropped in the spring, and run at pasture during the summer with their mothers, being weaned in the autumn. (Plate V., 2.)

West Highland.—It is thought by many that this picturesque breed is an aboriginal one, but whether this be so or not, it is certain that no cattle in the United Kingdom have retained in greater uniformity their characteristic breed points than the Highlanders have done. This seems to point to the conclusion that there has been little change in the character of this class of cattle, except that produced by a more careful system of breeding. The outstanding characteristic of the breed is its hardiness. Their wonderful constitutions enable them to stand exposure to cold and wet and to exist on pasture where other softer kinds would starve.

"The attempts to improve the West Highland by the introduction of alien blood have failed. The severity of the climate and the extreme poorness of the food in its native districts preclude early maturity and great size, and blending with other breeds could only result in loss of hardiness without increasing the symmetry of form and quality of beef." (Plate V., 3.)

Galloway.—The Galloway is another very hardy beef breed, in fact it is only surpassed in this by the West Highland cattle. A large number of Galloways are wintered in the open in Scotland and in the North of England. As a carcass of beef it is remarkable for its high proportion of lean meat of excellent quality. It does not grow very quickly nor mature very early, but for a beef breed it is a good milker.

Galloways are highly valued for crossing purposes; the cows are frequently mated with white, beef Shorthorn bulls, the result being the famous polled "Blue Greys." These cattle are very popular with both feeder and butcher for they inherit the most valuable characteristics of both the Galloway and Shorthorn parents. (Plate V., 4.)

DUAL-PURPOSE BREEDS.

Dairy Shorthorn.—Although in origin the Shorthorn was undoubtedly a dual-purpose breed, and in spite of the fact that the British farmer has always demanded a dual-purpose animal, yet at the end of the last century there was a very real danger that the dairy qualities of this famous breed would be entirely lost. The high prices offered for beef bulls by foreign buyers was largely responsible for this state of affairs. In the year 1906 some members of the Shorthorn Society, men of experience and foresight, formed the Dairy Shorthorn Association with the object of promoting the breeding of the dual-purpose type of Shorthorn which was then in danger of becoming extinct.

The Dairy Shorthorn as we know it to-day is a hardy, thrifty animal, full of quality and character; a regular breeder, and a good milker, some being very deep milkers indeed. Moreover, the milk

is of good colour and quality. When dry the cow rapidly puts on flesh and makes an excellent carcass of cow beef.

Dairy Shorthorn bulls are widely used by dairy farmers all over England. "The registration of non-pedigree dairy Shorthorn cows with authentic milk records is a feature of the work of the Dairy Shorthorn Association. These cows which are of the Shorthorn type and character are mated with pedigree dairy Shorthorn bulls with the ultimate object of qualifying their progeny for admission to Coates' Herd Book. The steers of this breed make excellent beef cattle, and are equally suitable for beeflings and mature beef.

LINCOLNSHIRE RED SHORTHORN.—This is a strain of Shorthorn which has been selected for colour and, in some cases, for milk production. That the cattle are very similar to a Shorthorn may be gathered from the fact that the Lincolnshire Red Shorthorn Association allow a red Coates' Herd Book bull to be used, and admit the progeny into their Herd Book. These cattle are rather larger than the average Shorthorn, coarser in bone, and lacking in that "style" for which the Shorthorn is so justly famous. They are remarkably hardy and free from tuberculosis. Their metier is the conversion of large quantities of coarse and inferior foodstuffs into meat and milk. Hence they are ideal for the rich alluvial soils which are their home.

Some herds are treated purely as beef cattle, but it seems probable that it is as a dual-purpose breed that its future lies. The cows of the dual-purpose strains are good milkers, and the calves, which are unusually large, can be fed into first-class carcasses of baby beef. Coarseness, a criticism which may perhaps be levelled against the Lincoln Red when mature, has at this age not developed. It will be realized that the characteristics of hardiness and freedom from tuberculosis already mentioned are of particular value when associated with dairy cattle. There seems to be some evidence that the dual-purpose Lincoln Red is more likely to breed true as far as milk production goes than many other dual-purpose breeds.

RED POLL.—This is the only hornless breed of English cattle. They are the result of crossing some 100 years ago the old Red Norfolk cattle, famous as beef producers, with the polled Suffolk cattle, famous for milk production. The result was a dual-purpose animal which suited ideally both the land and system of farming in the counties of its origin. Why the dual-purpose type should ever have been departed from it is difficult to see, but the fact remains that there are some herds bred with little or no regard to milk production. The Red Poll is rather tubular in shape, being long with well-sprung ribs, but lacking somewhat in depth. As baby beef it is exceptionally good.

As dual-purpose animals they are ideal for the poor light land farms of the eastern counties. Being moderate in size, and polled, they may be crowded together in yards much closer than would be safe with most other breeds, a decided advantage where a soiling system of feeding is adopted. For their size they are good milkers,

PLATE VI.

1. Red Poll Cow.

2. South Devon Cow.

PLATE VI. *continued.*

3. WELSH HEIFER

4. DEXTER HEIFER.

and the milk has the advantage of being a good colour. (Plate VI., 1.)

SOUTH DEVON.—The cattle of this breed are the largest not only of our British breeds but in the world. Mature bulls weighing over 30 cwt. have been exhibited within the past few years. They are pale red in colour and are generally inclined to be strong-boned and somewhat flat-sided. In spite of their apparent coarseness they are not unpopular with butchers, being particularly thick fleshed in certain parts of the carcass. The cows are very good milkers and the milk has a high percentage of butter fat. (Plate VI., 2.)

WELSH BLACK.—These cattle constitute one of the most ancient breeds and are said to resemble more closely than any other the cattle existing in this country in pre-Roman days. Until 1904 two breeds were recognized, the North and South, each with a separate herd book, but in that year the Welsh Black Cattle Society was formed with one herd book for the whole breed. Two types can still be distinguished however, the northern type being specially noted for beef and the southern for milk production.

Welsh cattle were in great demand at one period for draught purposes, hence the tendency, which it shares with some other breeds, bred until comparatively recently with this end in view, towards a heavy shoulder and light hindquarters.

As graziers' beasts the steers are well known in the midland counties of England, where under the name of Welsh Runts large numbers are fattened every year. Being extremely hardy, these Runts are particularly valued by those who have the grazing of exposed marshlands. The most valuable characteristics of the breed are the hardiness and the ability of the cows to produce good yields of milk under conditions in which cows of some other breeds would barely live. (Plate VI., 3.)

DEXTER.—This breed, which is an off-shoot of the Kerry, shares with it its excellent milking properties. It is a very small animal but is compact, blocky and substantial. The colour is either whole black or whole red. It is a dual-purpose animal, and the cows for their size are remarkable milkers.

Unfortunately, when bred pure they are apt to produce a proportion of monstrosities or "bull dogs," as they are called. These calves are either born dead or do not survive many days. The breed is frequently used for crossing purposes and when mated with Shorthorns or Aberdeen Angus produces some remarkably fine butchers' beasts. (Plate VI., 4.)

DAIRY BREEDS.

AYRSHIRE.—This is the only native breed of pure dairy cattle which has originated in the United Kingdom, and in conformation and appearance is typical of such breeds. The cow is wedge shaped, markedly feminine in appearance and distinctly angular and thin fleshed when compared with the beef or dual-purpose type. The colours are varying shades of red or brown patches on a white

ground. The most popular colour is a white body with red or brown patches in the neighbourhood of the head. The horns incline upwards and give the animal a characteristic appearance. Great stress is placed on the shape of the udder, which is distinctive. It should be long, wide and deep, but not pendulous or fleshy, and should be firmly attached to the body. It should extend well up behind and far forward, with quarters even, sole nearly level, and milk veins large, long and tortuous. The teats should be evenly placed, 2½ to 3½ in. in length, and hang perpendicular.

This type of udder with its firm attachment to the body, level sole and length forward is characteristic of this breed and may be contrasted with the pendulous type of udder seen in some other breeds. Unfortunately, the teats in many cows of the breed are inclined to be rather small.

The cattle are active and deer like, and are particularly suited for milk production on poor land. The male calves are rarely reared to maturity, the majority being used for veal. It is worthy of note that milk recording was first started in the United Kingdom by this breed society. (Plate VII., 1.)

JERSEY.—This race of cattle is native to the Isle of Jersey and has been kept pure for many generations by means of stringent import regulations. It is believed that no cattle have been imported for 200 years. All cows on the Island are therefore pure bred, but admission to the herd book entails inspection as well as registered parentage. No heifer is inspected until she has had a calf. This means that any animal in the Island herd book is not only pure bred but also that it reaches a certain standard of merit.

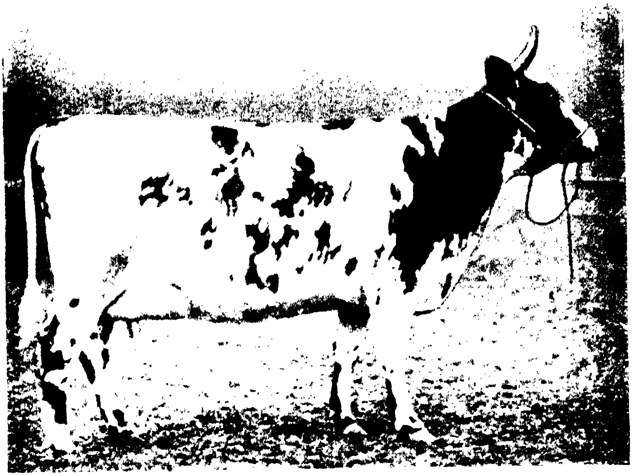
The Jersey is essentially a "butter" cow, and it is with this end in view that the cattle have been bred. Roughly speaking it takes only about two gallons of Jersey milk to give one pound of butter, and the butter is of wonderful texture, being waxy rather than greasy, owing to the large size and uniformity of the fat globules.

The cow is small and graceful, but is capable of giving a large return for a small quantity of good food. The colours of the Jersey are light and dark fawn, brown, silver grey and mulberry. The following are the points characteristic of the breed: Head, small and lean; face dished; eyes full and placid; horns neat, well formed, small and convex, well tinged with yellow; ears small, thin and yellow inside; neck and throat straight, thin and clean; back level, and broad at loins; barrel well sprung, deep at flanks; legs short and generally fine in bone throughout; tail long and fine; hide, thin mellow and of a yellow rich tinge; hair soft; udder symmetrical, full forward and behind; teats squarely placed and not too short; milk veins large and long.

The cows are gentle and docile but the bulls, despite their small size, are often fierce. The bull calves are killed for veal. The breed is very popular in the United States of America. (Plate VII., 2.)

GUERNSEY.—The islands of Guernsey, Alderney and Sark are the original home of the Guernsey cattle, which are kept pure there

PLATE VII.

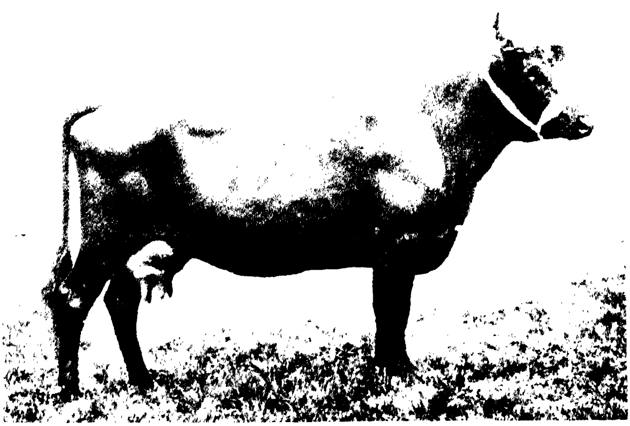


1. Ayrshire Cow.

2. Jersey Cow.

PLATE VII. *continued.*

3. Guernsey Cow.



4. Kerry Cow.

by similar restrictions to those adopted in Jersey for the protection of the native breed of that island. Of late years the Guernsey has become very fashionable in this country and the cattle are keenly sought after. Like the Jersey they are butter cows, giving good yields of very rich milk. They are rather larger than the Jersey cattle, stronger boned, and more robust. As regards colour, they are usually of a shade of fawn, with or without white markings. (Plate VII., 3.)

British Friesian.—For very many years prior to 1880, when an embargo was placed on all importations of cattle for breeding purposes into this country, there had been constant importations of Dutch cattle into East Anglia. In 1909 the British Friesian Society was formed to foster the interests of the breed, many of which had been kept pure. In 1914 an importation of some 50 specially selected Friesian cattle, under very strict quarantine conditions, was permitted. The subsequent progress of the breed in this country is unique. From 50 members in 1911 the membership of the society had risen to a thousand in 1919. In the former year the highest price paid for a single animal was £53. In the later year, when the boom in agriculture was at its height and all stock were making high prices, nearly 2,000 Friesians were sold at an average price of £174.

The British Friesian is a breed of large deep milking cattle of the dairy type, though they admittedly possess more dual-purpose characters than some of the other dairy breeds. Many of the good steers, however, which are sometimes seen and which are quoted as examples of the dual-purpose character of the breed, are Friesian mainly in colour and are by no means pure bred. The colour is black and white, though blacks and duns occur. The colours should be in sharply defined patches.

The cows are often exceptionally deep milkers and the average yield is high. At the same time the milk is often deficient in butter fat, and this is accentuated by its poor colour. Long continued selection for high milk yields without reference to quality is no doubt responsible for this state of affairs. That this need not be so is proved by the fact that some very deep milking individuals give milk with a comparatively high butter fat content. Breeders are alive to this defect in their cattle and are paying a great deal of attention to it, with the result that the best herds are rapidly improving in this important respect.

The Friesian is best suited to good conditions of housing and feeding, and responds well to generous treatment. The calves are large, often between 90 and 100 lb. at birth, and are born fat. This is an immense advantage for the production of veal. The mature steers are not as a rule first-class meat, the tendency being for them to grow and reach an undesirable size before they can be got fat.

Kerry.—This is a breed of small black cattle of pure dairy type, indigenous to the southern and western districts of Ireland. They

easily adapt themselves to their surroundings, are hardy, and are able to subsist on the scantiest fare and thrive where other cattle would starve. The Kerry is often described as the "poor man's cow," as she will eat almost anything and milk on it. They are sometimes used for crossing both with Shorthorns, Red Polls and Jerseys, the latter cross being of particular merit for milk production. (Plate VII., 4.)

TYPES OF CATTLE.

Although the breeds of cattle of this country vary considerably in appearance amongst themselves, they have nevertheless a number of points in common. Thus those breeds which are adapted for milk production resemble one another in several respects and differ markedly from those which are especially suitable for beef production. The characteristics associated with the particular form of production define the "type" and distinctive beef types and dairy types can be recognized even within the limits of a single breed.

The Dairy Cow.—A dairy cow, even when not milking, if fed freely, does not readily store fat on her body, and in consequence her bones seem loosely held together, and are clearly visible because of their sparse covering of flesh (Plate VIII.) This prominence of bone is known as "angularity." When standing a short distance from a typical dairy cow it will be noticed that she has three dairy "wedges": these are made by (*a*) the horizontal top-line of the body and the under-line which as it is deep at the udder and less deep at the chest would converge with the top-line if both were continued; (*b*) the wide base of the chest and the narrowness of the backbone behind the shoulder blades; (*c*) the wide hocks and narrow shoulder tops.

The first dairy wedge is produced principally by the capacious body containing the large digestive tract which converts food and water into raw materials for milk production. Frequently body capacity is abbreviated and called "capacity." In addition to the wedges a good dairy cow must have a large udder. The general appearance of body and udder of the dairy type is markedly different from that of the beef cow.

After the superficial points have been observed (Fig. 84) she should be carefully examined systematically as follows: head, neck and forequarters, body, hindquarters, mammary development, quality.

A refined, thin-fleshed feminine dairy head is required with fine face bones and horns. Although the shape of the head varies with the breed, usually the dairy head is long from eye to nose, narrow at the eyes and broad at the nose. A large nose is thought to indicate a good constitution, while it is contended that a large mouth facilitates food consumption.

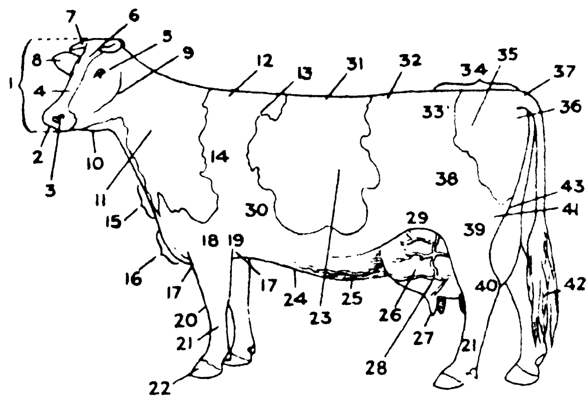
PLATE VIII.

BREEDING BEEF AND DAIRY TYPES.

The eye, although alert, must not be excessively so for this indicates a nervous animal which may be easily influenced by external factors and hence an erratic milker. The refinement of the head should be continued in the long thin neck and light forequarters all blending to give a smoothness, despite the characteristic angularity. The fine shoulders, close at the points, should be neatly laid to the body, producing no definite hollows behind them in the crops. The cow should stand evenly on her sparsely fleshed, fine boned legs.

A wide chest indicates a constitution adequate to stand the strain of milk production, and a large heart girth the presence of large heart and lungs, though it has not been proved that cows with this

FIG. 84.—POINTS OF A DAIRY COW.



1.	Head.	12.	Withers.	23.	Barrel.	34.	Pelvic Girdle.
2.	Muzzle.	13.	Crops.	24.	Milk Well.	35.	Thurls.
3.	Nostril.	14.	Shoulder.	25.	Milk Vein.	36.	Pins.
4.	Face.	15.	Dewlap.	26.	Udder.	37.	Tail Head.
5.	Eye.	16.	Brisket.	27.	Teats.	38.	Stifle.
6.	Forehead.	17.	Chest.	28.	Udder Veins.	39.	Gaskin.
7.	Horn.	18.	Forearm.	29.	Flank.	40.	Hock.
8.	Ear.	19.	Elbow	30.	Heart Girth.	41.	Thigh.
9.	Cheek.	20.	Knee.	31.	Back.	42.	Switch.
10.	Throat.	21.	Shank.	32.	Loin.	43.	Twist (inside leg).
11.	Neck.	22.	Hoof.	33.	Hooks.		

characteristic necessarily have good constitutions. The body, or barrel, should be long from the shoulders to the hocks and with well sprung, deep ribs to provide capacity for food.

Typical hooks and pins are large, and set wide apart to produce the points from which the udder is suspended. In addition, width between the pins is thought to facilitate calving. The muscles of the hindquarters should be sparsely covered with fat and therefore clearly visible; viewed from the side they should produce a straight line from the pin to the hock. The thighs should be thin to allow ample space for a large udder, which, when full of milk, will force the legs as wide apart as in a beef cow. The appearance of the cow

is enhanced if the tail is set on neatly and level with the backbone, without being either too high or low.

Cows producing large quantities of milk usually have capacious udders, wide and carried high up to the tail, and far forward along the underside of the body. A large udder does not necessarily mean high milk production for the udder may contain fat and not the essential glandular tissue. It is easy to distinguish fatty and glandular udders. During the day the glandular udder varies considerably in size for it is very large immediately before milking and small afterwards, but milking has little or no effect upon the size of the fatty udder. As lactation advances the glandular udder gradually shrinks but the fatty udder remains constant in size. The task of differentiating between them is however difficult if the udders are full of milk, for then they may deceive even the best judges. The empty glandular tissues, after milking, are exceedingly spongy and elastic and pleasant to handle but those of a fatty udder are heavy and non-elastic.

An udder cannot be considered good unless the component quarters are all uniformly good. A medium-sized teat well placed in each quarter simplifies milking.

When the udder is covered with fine skin and short silky hair the small veins on the outside of the udder are seen clearly. The venous blood is conveyed mainly from the glandular tissue of the udder by six veins but only the two which run from the front of the udder along the body are visible. These two veins, the "milk veins," run, one on each side of the body, along the under side of the barrel and then turn suddenly to enter the body cavity. The point of entry of the milk vein is called the "milk well." Only two milk wells are found normally on a cow but in especially good milking cows the milk vein may divide several times producing several milk wells. The area of a cow's milk wells is so closely connected with her milk production that it is a reliable indication of her milking propensities. The fingers may be used to measure the size of the milk wells. A well which will accommodate the tip of the middle finger of an average man's hand is considered large. Care must be taken to examine all milk wells on both sides of the cow for considerable variations occur from one side to the other. For some unaccountable reason stockmen like to see the milk veins tortuous, or winding, but it is difficult to understand how this can be associated with high milk production.

It is generally accepted that fine bone and skin indicate quality in dairy animals. The fineness of bone can be most easily seen on the legs and tail, where only a little flesh is carried. The skin is easily influenced by the feeding and health of the cow and although a thin pliable skin on the ribs is preferred it is an unreliable indication of quality. The skin should be so plentiful over the ribs that the hand just laid flat over the ribs may be closed slowly and gather a handful of it.

Probably the skin on the udder is little affected by feeding and if plentiful, in folds and pliable, it is ideal.

The Dairy Bull.—It is difficult to describe a dairy bull because there is so little which safely indicates his true dairy transmitting ability. He must be masculine in general appearance, yet have many of the characteristics of the dairy cow. His head must be heavier than that of a cow, wide between the eyes and fairly long from the eye to the nose, but in other respects his head will resemble a dairy cow's. A true masculine neck is thick, with a high crest, and although long it appears short and thick.

The forequarters, body, and hindquarters should be as nearly like those of a good cow as possible, but the barrel is not as well developed as in a cow. The mammary development of a bull is shown by the rudimentary teats and their placement. These teats should be well placed and preferably further forward than the scrotum. Some bulls have quite large milk wells and it is assumed that this is desirable.

It is particularly important that the bull should be refined and show an abundance of quality. Finally, bad faults such as high tail setting, shallow depth of chest, badly sloping rump, although not utility points, would, in the eyes of experts, reduce the value of a bull's progeny if they were transmitted.

It will be shown later that more important points than those of conformation must be considered when purchasing a dairy bull.

The Beef Cow.—Whereas the dairy cow is adapted to milk production the beef cow must be correspondingly adapted to the production of flesh. This must be laid on the skeleton in the correct places. Where it is most particularly required can be best understood from the following table and Fig. 85 :—

BUTCHERS' CUTS IN A SIDE OF BEEF.

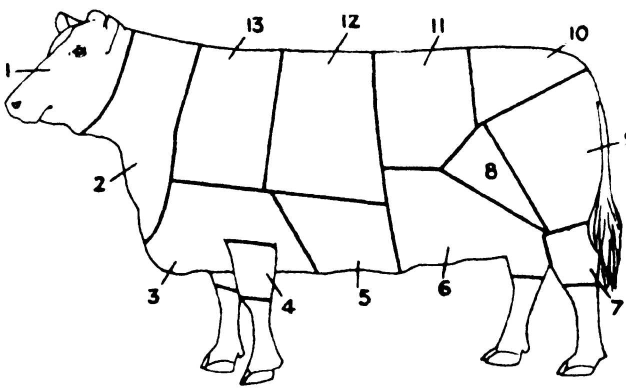
Name of cut.	Retail Price per lb. (1930 prices).		Uses.
	s.	*d.*	
Rump	2	0	Grill
Loin	1	6	Roast
Round	1	3	Roast
Best Ribs	1	3	Roast
Thick Flank	1	2	Grill or Stew
Back Ribs	1	0	Roast or Stew
Shin	0	9	Stew
Clod	0	9	Stew
Leg	0	9	Stew
Plate and Brisket	0	8	Boil and for cold Meat
Thin Flank	0	7	Boil

Although the prices fluctuate seasonally the same relative differences persist. It will be noted that the high priced cuts, the

roasting joints, are at the hind end of the animal, and the cheap stewing cuts are at the fore end. The roasting cuts sell well throughout the year but the stewing cuts are required mainly during the winter. Thus the butcher likes an animal particularly well fleshed in the hindquarters and light in the forequarters. In districts where the side of beef is halved at the seventh rib, the fore and hind ends should be about equal in weight, but a good carcass will be heavier in the hind end and a poor one heavy in the fore end.

The main feature of the beef type is rotundity and smoothness, for a well finished beef animal has no bones protruding, being well covered with flesh everywhere. Whereas the dairy cow is put

FIG. 85.—DIAGRAM OF BUTCHER'S CUTS ON A BEEF COW.



1. Head.
2. Clod and Sticking.
3. Brisket.
4. Shin.
5. Plate.
6. Thin Flank.
7. Leg.
8. Thick Flank.
9. Round (Topside and Silverside).
10. Rump.
11. Loin.
12. Best Ribs.
13. Chuck and Ribs.

together loosely the beef cow is firmly, solidly, and compactly built, standing close to the ground, the beefy blockiness replacing the dairy wedges.

The details of the conformation of the beef cow from the butchers' point of view, are as follows :—

The beef head is neat, short and thick with large nostrils and mouth, and no coarse bones, and in many breeds a poll instead of horns. The absence of horns may appear to add to the blockiness of the head. The neck should be so short, thick and well fleshed that the outline of the muscles and gullet cannot be distinguished. The shoulders must be neatly joined to the neck and body with an abundance of flesh. The meat must be laid on both sides of the shoulder blades, making the points of the shoulders wide apart at the top line and the legs far apart at the under line. Although a

good beef cow must have a wide heavy brisket and dewlap, it is difficult to understand the reason, for the brisket is low quality meat.

A butcher requires an animal with a long body, well-sprung ribs, and good loin to satisfy the public demand for the better cuts of meat. Thus the width must increase from the shoulders to the hind end. The back must be flat. The ribs, although deep, need not be as deep as in the dairy cow for the beef under line should be parallel with the top line. Flat-sidedness is to be avoided, for ribs from such animals contain insufficient lean meat for the public demand. Good constitution as indicated by depth and width of chest is required.

As the hindquarters produce the most valuable cuts they must be so well covered with flesh that the hooks and pins are submerged in flesh. The pins and hooks must be far apart to allow for the development of the valuable rump meat. The thighs should be so well fleshed, particularly between the legs in the twist, that they bulge with meat whether viewed from the side or the back. Both the hind and fore legs must be short and wide apart carrying the body close to the ground. It is obvious that if the twist is well filled little space remains between the hind legs for an udder. Only a small udder is required, for a beef cow is expected to produce merely sufficient milk to rear her own calf. Thus in beef cows mammary development may be ignored, except occasionally where beef cows are such poor milk producers that they do not produce a sufficiency for their own calves, for in beef-breeding herds no additional milk is available.

A good butcher's animal has small fine bones evenly covered with good quality meat with only a limited proportion of fat. Fine bones, as with the dairy cow, can be easily judged on the legs and tail where little flesh exists. In addition to the fineness of bone the hair and skin are considered to indicate the quality of meat, but they are not infallible signs.

Fleshing can be judged by applying several standard tests :— along the backbone ; over the ribs ; over the loin ; over the hindquarters ; and over the flanks. The fleshing along the backbone can be judged by tapping it with the tips of the fingers, with a supple wrist. With even fleshing a uniform feeling is experienced, but if fat and bone are felt the fleshing is uneven. If the flat hand is passed over the ribs, loin and hindquarters the evenness of fleshing can again be judged. Uneven fleshing is most likely to occur on the pins and ribs where excessive fat production leads to the objectionable " blubber " which was, at one time, so common. The flank may be taken in the hand to ascertain the thickness of fat.

The Beef Bull.—It is much easier to judge a beef bull than a dairy bull. A beef bull suitable for breeding should be an excellent butcher's type of animal, but in addition he must have the requisite male characters in head, crest and scrotum. Special care must be taken to judge his fleshing qualities for it would be most undesirable

to use a bull covered with patchy fat. Any bull with coarseness of skin, hair, or bones should be avoided, for he might beget offspring producing coarse quality meat.

The Beef Steer.—The steer should display none of the secondary sexual characters commonly associated with masculinity in the head and neck, but the cod (scrotum) provides a reliable means of judging his fatness. As it is usually the last part to become fat a well finished cod indicates a well finished bullock. In all other respects the good steer or bullock will have the same corresponding points of conformation as the beef cow described in detail above.

The Dual Purpose Cow.—As dual purpose cattle are more numerous in this country than either pure beef or dairy stock they must have some definite advantages over the other types. Their popularity is due largely to the troubles that occur in dairy herds when animals are annually culled for bad udders, non-breeding, etc. Such cows culled from a dairy breed are of little value but those from a dual purpose herd may be fattened advantageously.

The type can be best realized if the expectations from a dual purpose cow are stated. It should :

(1) Yield at maturity at least 8,000 lb. of milk per lactation of 315 days.

(2) Calve annually, producing stock which will breed true to the dual purpose type.

(3) Produce male calves which, if castrated, will fatten readily for baby beef or mature beef production.

(4) Fatten herself at the end of her milking days, and, depending on the current prices, be worth about £20.

It is obvious that a good dual purpose animal must have a combination of both beef and dairy characteristics, but it is impossible to obtain the ideal, for the beef conformation is often the exact opposite of the dairy conformation.

The dual purpose type is essentially the dairy type but masked by fleshing, for a dual purpose cow is rarely as thinly fleshed as a cow of a true dairy breed. If the cow is carrying much flesh she, at first sight, may appear to be beefy, but her big frame, particularly wide hooks and a large udder would betray her true identity.

A dual purpose cow may milk as well as the cow of a dairy breed, but she is inferior to a beef cow for beef production. This can be most easily observed when the dual purpose cow is fat for slaughter. Some characteristic faults then appear. The fleshing is frequently uneven and patchiness is visible over the hindquarters, ribs, loin and back. In addition the hindquarters are never as well fleshed or finished as those of a beef animal, for the hooks of the dairy type are wide and difficult to cover and the thighs and twist are never well filled.

In breeding it is exceedingly difficult to obtain the ideal combination of meat and milk. Further, some dual purpose animals do not breed true and the progeny may be either beef or dairy or some rather valueless inter-grade. Thus a good dual purpose

animal is more difficult to breed than either a good dairy or a good beef animal.

The Dual Purpose Bull.—It is exceedingly difficult to describe the type of a dual purpose bull for his power to transmit the capacity for producing milk can be judged only by his offspring. Fundamentally his type must be dairy, with no strong indication of beefiness, but it must be remembered that the amount of flesh carried may be influenced largely by feeding.

SELECTING BREEDING STOCK.

Anyone commencing live stock farming must first carefully consider his policy and must decide whether he will buy pedigree or non-pedigree stock. Pedigree stock are those whose ancestors for many generations are known and are recorded in a book known as a "Herd Book." Each different breed of stock has its own herd book. The progeny of pedigree stock may automatically enter the herd book if a few minor regulations are observed.

Pedigree stock are usully a definite type, so well fixed by generations of breeding that they breed sufficiently true to maintain it. Because of the greater certainty of the progeny pedigree stock usually command a higher price than non-pedigree stock. For a person starting stock breeding the purchase of pedigree stock involves a slightly greater initial outlay. Till a newly formed pedigree herd has become conspicuous by either winning prizes at shows or by milking well, the stock when sold may not make pedigree prices. Thus it may be some years before satisfactory returns can be obtained when selling.

Further, the beginner, with no previous experience of stock, may make mistakes in feeding and management which may result in loss of condition, ill health and in extreme cases, death. Experience with non-pedigree stock costs less than with pedigree stock. The possibility of grading up non-pedigree stock to pedigree by using pedigree bulls for several generations is worth consideration.

The following discussion of the selection of breeding stock, although applying to non-pedigree stock, refers more especially to pedigree stocks.

Choice of Breed.—The initial choice of a breed depends on many factors, one of which is the preference of the individual breeder.- He must also consider whether he requires beef, milk or dual purpose breed. If milk then whether the aim will be to produce fluid milk, cream, butter or cheese. The selection of the breed will also be influenced by the locality, climate and cropping. Some breeds are more hardy than others and some are big cattle needing much bulky food. Where food is scarce, small animals with correspondingly small appetites should be chosen.

Cattle Judging.—Having decided upon the breed to purchase it is then necessary to gain some experience of judging to assist in the purchase of the cattle and also for subsequent breeding and culling.

Although show cattle judges are born, not made, anyone who is interested in cattle may in time become quite an efficient judge of them. It is necessary first to obtain good mental pictures of the ideal cattle types and then to look at stock very thoroughly and compare them with their corresponding ideal type. If a decision has to be made between buying one of two animals it is usually desirable to compare each point of the one with the corresponding point of the other. To examine an animal thoroughly, a student may find it helpful to use a score card, as illustrated:—

BEEF CATTLE SCORE CARD.

	Maximum Points.
General Appearance—20 per cent.	
Weight for Age ...	7
Form.—Blocky and compact; level top and underline; broad, deep and square, both meeting you and leaving you well. Short on the legs ...	9
Style and Carriage ...	4
Head and Forequarters—11 per cent.	
Head.—Showing quality. Face short, wide between eyes. Eyes large and placid. Muzzle and nostrils broad. Mouth, large	4
Neck.—Moderately short and thick, neck vein full of flesh. Smoothly joined to shoulder ...	2
Shoulder.—Well covered with flesh, wide between blades, wide over chine, smoothly laid ...	3
Brisket.—Wide, projecting well forward between forelegs ...	1
Forelegs.—Short and wide apart ...	1
Body—27 per cent.	
Chest.—Wide and deep ...	4
Crops.—Well filled, even with shoulders ...	3
Ribs.—Well sprung and deep. Large heart girth ...	6
Back.—Broad, straight, smooth ...	5
Loin.—Wide, not narrowing down behind ribs ...	6
Flank.—Thick, heavy, well let down ...	3
Hindquarters—27 per cent.	
Hips.—Well covered, moderately wide ...	3
Quarters.—Long from hooks to pins, wide through thurls, rump well filled ...	10
Tail Head.—Neat, absence of patchiness ...	3
Thighs.—Full deep, wide from behind ...	5
Twist.—Full deep. (Steers, cod or purse full) ...	4
Legs.—Straight, short and wide apart ...	2
Quality and Touch—15 per cent.	
Evenly covered with firm springy muscle, absence of patchiness	6
Skin pliable, soft, moderate thickness ...	4
Whole animal covered with fine mossy hair ...	2
Neat fine bone ...	3
Total ...	100

The score card is, as it were, a measuring staff to place beside the cow, with the ideal animal as the standard. If judging two animals at a time a beginner may find it easier to compare them point by point and to give each one with the best point full marks and so

on throughout the score card. Whatever system is followed, first stand well away from the animal in order to form a general opinion, and then examine in detail, commencing with the fore end and working to the hind end, and finally handle the necessary parts. Move the stock again after they have been judged standing, for then lameness or joint trouble shows up most clearly. Stock may be very nervous and easily frightened if a stranger moves quickly near them, thus particular care must be observed when handling strange cattle.

Breeding Policy.—Before purchasing stock, the breeding policy must be planned to suit the circumstances. The common systems of breeding are in-breeding, line-breeding and out-breeding.

In-breeding is the mating of very closely related stock together, *e.g.*, brother and sister mating, dam and son mating, or sire and daughter. This is done in order to concentrate in the progeny certain characteristics present in the parents, but as both good and bad points may be accentuated it is a risky procedure. It should only be followed where the foundation stock are unrelated and have no obvious bad faults. This policy involves greater risks than most breeders can afford to take.

Line-breeding consists of mating slightly related stock together. Again the aim is to concentrate certain points but it involves much less risk than does in-breeding. Frequently the system may be used with advantage in dairy breeding. Thus, when it has been found that a bull from a certain family has left good milking progeny in the herd, then other bulls may be used from that same family.

Dairy Males.—The dairy bull may be the parent of sixty calves per annum but the best cow in the herd is rarely the parent of more than one calf in the year. Thus the bull has as much influence on the future herd as all of his cows. If he impresses his type upon his progeny he may be equal to more than half the herd. Thus a bad bull may have very deleterious effects upon it. The cheapest and quickest way of improving a herd is by using the right sire. Great care must therefore be taken in selecting a bull and a big price may be paid for him. If a dairy herd has a low average milk yield, it is easy to increase the yield by breeding but with a high average it is exceedingly difficult to raise it further yet very easy to lower it.

The following points must be considered before buying a bull, though not necessarily in the following sequence which has been arranged to emphasize points often omitted : ability to produce good milking cows ; bull's pedigree ; appearance of bull's progeny ; appearances of bull's dam ; appearance of the bull.

By the time a bull has shown his ability to breed good producing cows he will be an old bull for if, when 12—15 months old, he serves his first cows, their heifers will not complete their first lactations till he is over five years old. Unquestionably a bull which has proved that he can transmit high milk production to his stock, is the one to use, for the breeding results are more certain. The

value of an old bull can be judged by the milk yields of all of his daughters, compared with those of their respective dams, but sometimes allowances have to be made such as mentioned on p. 620.

A pedigree is merely a chart showing an animal's ancestry but frequently in addition it gives production records and showyard winnings of the stock may be mentioned. As a good bull is one that has been especially bred for high production this should be shown by the milk production records of his near female relations. It is rarely necessary to consider the production of more than the dam, two grand dams and occasionally the four great-grand dams, although salesmen may stress more remote animals. Both of the parents should be from high producing stock and preferably the bull's nearest relatives should show the highest production. Some pedigrees are filled with irrevelant material such as records of unrelated stock which must be ignored. As some bulls are now proven they may be especially marked in future pedigrees.

Cows should have shapely udders, and in the heifer special care must be taken to see the udders are of good shape with the teats well placed.

If a young bull who has no progeny is being considered it is desirable to see his dam for if she has good mammary development it may be assumed that the bull will transmit something similar to his progeny. The dam must be of a good dairy type with no bad faults.

The appearance of the bull has purposely been left to the last for frequently it is the only thing considered. The bull should be of typical dairy conformation with no bad faults which he might transmit.

Dairy Females.—Essentially the dairy female must be of good dairy type and, if she has been milked, she must have a high milk production record. Her ancestors, too, should have good records. The pedigree should be studied much as suggested when purchasing a dairy bull. If the female has progeny it is advantageous to see them, for it will indicate whether good or bad points are being transmitted.

Beef Stock.—As the beef type can be so easily judged it is almost safe to select breeding stock on inspection only, but if a pedigree gives the winnings of the stock at recognized fat stock shows it may be particularly helpful.

Starting a Herd.—After the beginner has decided upon the kind of stock he wishes to buy he has to consider the source from which to purchase the stock, for unless he takes precautions he may introduce to his farm such serious contagious diseases as tuberculosis, contagious abortion, garget, anthrax, white scour of calves, or foot and mouth disease. Stock may be obtained from dispersal sales, collective sales, by private purchase, through dealers, or by purchase at a local market.

On the retirement or death of an owner a herd may be dispersed which represents the life work of a breeder in obtaining a certain

uniform type or production. Thus the purchaser might save many years of breeding if he took a number of the better animals to form the nucleus of his herd. Again, animals from the same herd settle well but strangers may injure one another. Breeders know that at such a sale, depending on the breeder, some good and, possibly, some bad stock may be sold.

As breeding increases the head of stock annually some breeders are forced either to have a sale on their own farms, or several breeders may combine and send their stock to a collective sale. Naturally, a breeder wishes to sell his poorer stock, but if only poor animals were offered other breeders, knowing this, would not attend the sale. To attract trade some good animals are therefore sold. If the poorer animals predominate the prices are generally low, and thus, with care, a purchaser may select good animals and buy them cheaply. It should be remembered that the greater the number of herds from which animals are brought the greater will be the chance of introducing disease.

Either a whole herd or individual animals may be purchased privately and it is a system with many obvious advantages. It has one disadvantage, for by visiting the farm the purchaser admits keenness to buy and the owner may have to be tempted to sell by the offer of a high price.

Some farmers, mostly non-pedigree breeders, order cattle from cattle dealers. Although the system is very useful when obtaining store cattle it is hardly to be recommended as a means of purchasing pedigree stock. There is the grave risk of introducing disease by buying in this way.

Diseased, unthrifty, poor milking, non-breeding stock which can be sold by no other means are consigned to local markets, but good breeding stock can usually be sold by other means. Thus it is obvious that only store and fattening cattle should be purchased from such a source.

CATTLE FEEDING AND MANAGEMENT.

If cattle are to be successfully reared their requirements from birth to maturity must be fully understood. The procedure varies according to climate and stock, for dairy stock require different treatment from beef cattle, and breeding stock from fattening stock. For simplicity the feeding and management of cattle may be discussed under the following headings:—Dairy Females, Dairy Males, Beef Breeding Stock, Beef Fattening Stock.

Dairy Females.—Although stock raising is expensive, all successful dairy farmers must breed their own stock, for it is the only satisfactory way of improving a herd. A natural sequence of discussion is from the calf to the mature cow.

Many methods for calf rearing are used, but certain points are common to all systems. Until the calves are three months old they must be fed regularly with clean wholesome foods in the correct quantities. If the food is liquid, it must be given at the

correct temperature (100° F.) All calves must first receive colostrum from their own dams or some milk containing castor oil to open their digestive tracts. Until the end of the third week the calf should be fed three times daily but thereafter twice should be adequate. When calves are given liquid foods they should be housed either in individual pens, 4 ft. by 6 ft., within sight of one another, or tied up during, and for a short time after feeding to prevent them suckling one another. The pens must be clean, well littered with straw, and, unless the calves are fattening for veal, adequate lighting is essential.

Calves other than pedigree bull calves are reared normally by one of the following systems. The natural method of feeding is for calf to suckle its own dam but it is too expensive unless either it is an exceedingly valuable calf or the dam is a cow which has milked well but because of injury or loss of a quarter is kept for breeding and suckling. Such a cow should be able to suckle several calves in addition to her own during her lactation, for a heifer calf is suckled for only two to three months and a foster mother may produce sufficient milk at the beginning of her lactation to suckle three calves. The cow may suckle up to 12 calves in her lactation. This system depends upon a good foster mother which will take readily to calves. for if she does not let them suckle she will have to be watched lest she kicks and injures them.

On most dairy farms milk is too valuable to feed in unlimited quantity to the calves but on a few outlying farms, where it is difficult to sell milk, pail rearing is practised. When whole milk sells for a good price calves are fed with the minimum of it which may be supplemented, and finally replaced, with gruel. When several days old the calf should receive about one gallon of milk and as its appetite increases it may receive one and a half gallons by the end of the third week. The minimum amount of whole milk for rearing is 30 gallons. After the third week gruel may be fed consisting of one of the following mixtures :—

2 parts linseed cake or meal, 2 parts oatmeal, 1 part ground linseed.
6 parts pea meal, 3 parts ground malt and 1 part ground linseed.
1 part linseed cake, 1 part middlings.
A proprietary mixture especially if containing a milk product.

The gruel should be carefully made by mixing one pound of meal with one gallon of water and heating it gradually for several hours until it boils. It is then cooled to the correct temperature for feeding. The gruel should gradually replace the whole milk which should be fed only until the calf is two months old, by which time the ration will be two gallons of gruel. This system and the difficulty of keeping the buckets clean involves much labour and as it gives no better results than other more simple systems, it is not to be recommended.

The most common system in use on dairy farms is pail feeding with limited new milk and dry supplements for it is both simple and efficient. New milk is fed in exactly the same way as

above, but the gruel which needs careful preparation is replaced with dry concentrated foods. When the calf is three weeks old it will eat a little cake; the quantity should be slowly increased daily until at eight weeks old one and a quarter pounds may be eaten and two and a half pounds at three months. The mangers must be cleaned out daily to keep them sweet. The meals may include any of the following :—

4 parts linseed cake and 5 parts whole beans or bean meal;
2 ,, ,, ,, 1 part of crushed oats;
1 ,, ,, ,, 1 part whole beans or bean meal and 1 part crushed oats;
4 ,, ,, ,, 3 parts maize meal and 1 part fish meal;.
4 ,, ,, ,, 5 parts wheat or middlings and 1 part dried yeast.

Pail feeding with limited new milk, supplements and either whey or skim milk is practised on dairy farms in districts where butter and cheese are made. Large quantities of skim milk and whey are produced which must be utilized quickly. These by-products can be fed conveniently to calves provided they receive whole milk during the first three weeks of their lives. The by-products vary in composition and the supplements must be adjusted accordingly. As skim milk is ordinary milk with the fat removed, the supplementary concentrates must be high in fats or carbohydrates. Thus either one half to four ounces of cod liver oil or extra cereals must be fed in addition. A suitable ration is two parts crushed oats and one part of bran meal, or linseed cake.

With cheese-making the proteins are removed from the milk leaving whey. Thus a supplement high in proteins such as :—

(*a*) two to three parts linseed cake two parts crushed oats one part fish meal;
(*b*) two to three parts linseed cake two parts fine middlings one part fish meal

should be used.

The by-products may be introduced into the ration gradually replacing the milk till no milk is fed when the calf is eight weeks old. More than two gallons of whey or skim milk should never be fed daily, for large quantities distend the abdomen. When three months old the calves should consume two pounds of meal and one and a half gallons of whey daily.

Only the milk and concentrates for calf rearing have been discussed but calves require other foods in addition. Calves need the best quality meadow hay for they only eat one and a half pounds daily at three months. To avoid waste this may be fed in strong nets and when not eaten it should be removed daily. Small quantities of roots may be given when the calf is over three months old but silage is better omitted till the calf is older. There is some evidence that calves make better live weight gains when receiving minerals, and unquestionably they are better when given an opportunity of licking rock salt. As the food of calves housed during the winter may be a little deficient in vitamins some authorities advise feeding cod liver oil, but no definite ruling can be given.

Calves need water, particularly when the milk is reduced, but ***they must not consume too much for an excess may spoil their*** **conformation.**

Dairy calves should be housed till they are six months old unless, either they are suckling a foster mother who is grazing during the summer, or they are well grown and healthy when the spring arrives. As pail feeding ceases when the calves are three months old several calves may be placed in one pen to reduce labour. As they are still very young they must receive good quality food, though not necessarily the best. A suitable ration is shown on p. 535.

In sheltered districts dairy heifers may graze from the age of six months until the period of pregnancy. It must be remembered that young heifers may pick up hoose or husk if put on damp pastures. When first turning cattle out to grass they must be carefully watched lest they eat too much, as this may either make them scour, or cause them to become blown. The first grazing should be restricted to a few hours daily, and a small quantity of high carbohydrate concentrates fed to counteract the high protein content of the grass, or hay may be given to prevent scouring. When the heifers are grazing safely they may receive no more concentrates until shortly before they calve. If such heifers are to graze during the winter they should have access to a covered shed for bad weather. When the ground is covered with snow or frozen hard they should be given some second quality hay.

Rarely, save in sheltered districts, should heifers under twelve months old be kept grazing during the winter and preferably they should be housed in yards and fed cheaply on hay, straw, roots, silage, and a small quantity of concentrates. Housed heifers over twelve months old require cheap bulky foods to develop their digestive tracts. In addition they may require a little highly concentrated food, *e.g.*, ground nut cake, or decorticated cotton seed meal, for adequate growth.

Breeding.—Before discussing mating it is necessary to explain the signs of "heat" in the non-pregnant females. These occur at 21 days intervals. When a number of heifers are running together in a field or yard they may jump one another, but only the heifer on heat will stand while another heifer jumps on her. An isolated heifer on heat bellows to other cattle and they may reply. Milking cows give less milk for the day they are on heat. During the winter the signs of heat are less pronounced and the duration of the heat period is reduced to a few hours. Thus it is difficult to get cows to calve in the autumn, for they have to be served during the winter.

The age of the first breeding of a heifer depends upon her breed and her size. Heifers of the large breeds drop their first calves when 27 to 36 months old but the small Channel Islands breeds frequently have calved when 24 months old. The differences within a herd are due to the development of the heifer and to the requirements of the farmer. Lactation throws a big strain upon an animal

DAILY RATIONS FOR DAIRY CATTLE.—(BASED UPON DAIRY SHORTHORNS).

Age in Months.	Live Weight of Animal in cwt.	Concentrated Foods Fed.	Roughages Fed.	Succulents Fed.
3	¾ to 1½ cwt.	6 quarts milk till 8—12 weeks old. ¼ lb. 1 part linseed cake; 1 part ground oats at 3 weeks, increasing to 2½ lbs. at 3 months	Good meadow hay at 3 weeks, increasing to 2 lb. at 3 months	5 lb. mangolds at 8—12 weeks.
6	3 to 3½ cwt.	1 part linseed cakes, 1 part crushed oats } 4 lb. *or* 1 part bean meal, 1 part linseed cake } 4 lb.	5 lb. medium meadow hay	10 lb. roots or 5 lb. silage
		or 3 parts crushed oats, 1 part linseed cake } 2 lb.	*or* Grass	*or* Grass
9	4½ to 5 cwt.	1 part cracked beans, 1 part crushed cereal } 4 lb.	5 lb. medium or poor hay	15 lb. roots or 8 lb. silage
		or Grass	6 lb. oat straw *or* Grass	*or* Grass
12	5½ to 6 cwt.	2 parts crushed wheat or barley, 1 ground beans or palm kernel cake } 3 lb.	10 lb. poor hay 6 lb. oat straw	20—30 lb. roots *or* 14 lb. silage
		or Grass	*or* Grass	*or* Grass
18	7 to 7½ cwt.	Nil *or* Grass	14 lb. poor hay straw *ad lib.* *or* Grass	35 lb. roots or 15—20 lb. silage *or* Grass
24	8 to 9 cwt.	Nil till 2—3 months before calving commencing with 2 lb. palm kernel cake ... ... Increasing before calving to 6—8 lb. concentrated as fed to the dairy cows *or* Grass	16 lb. hay 10 lb. straw *or* Grass	40 lb. roots *or* Grass

and if it commences unduly early in life body growth may be restricted. Thus heifers must be well grown before they are served. In addition calving times must be arranged in accordance with the owner's requirements of milk. Consequently a heifer may, in practice, be served when younger or older than the average of 18—21 months.

Usually dairy cows are served three months after calving so that with a nine months gestation period they will calve again twelve months after the previous calving, but with dairy heifers which have calved at a very early age service may be delayed for three months to give them a long dry period prior to their second calving. Some breeders do not serve their best cows till four or five months after calving. This enables such cows to give high lactation milk yields and reduces risks as calvings are less frequent. The disadvantage of this system is that the best cows leave fewer calves during their life-times than the others. Also by delaying service after calving it becomes increasingly difficult to get the cow in calf. Finally calving every 14 or 15 months may result in the cows calving at inconvenient times. A heavy bull may permanently disable a heifer. It is rarely safe to use a bull of more than twice the weight of the heifer unless a breeding crate is used.

The indications of pregnancy are, in the first place, the absence of the indications of heat. In the heifer, several months after the commencement of pregnancy the udder develops. At the fifth month there is a marked fall in the milk yield of a lactating cow.

As the initial stages do not exert any big strain upon the heifer she may be fed according to her live weight, and if the weather is suitable the in-calf heifer should graze. Similiarly a pregnant cow may be fed according to her milk production till she is dry or is dried off at six to eight weeks before calving again. If a cow or heifer is in poor condition she must be fed concentrated foods two or three months before calving to give her some surplus flesh for milk production immediately after calving. Initially four pounds of concentrates balanced for milk production might be fed and the quantity increased as calving approaches, depending on the condition of the animal, to 10 or 14 lb. daily. It is desirable to feed the same concentrates before calving as are to be fed after calving to facilitate subsequent feeding.

The concentrates may be fed in mangers in either a yard or a shed in order to bring the cows and heifers under observation. The heifers thus become used to attention, a feature of value if assistance is needed at calving. In addition, the udder must be watched, for if it is either developing unevenly or becoming a little hard it should be massaged daily. After such treatment a heifer usually takes kindly to milking. Cows and heifers from deep milking families may fill their udders prior to calving ; some authorities advise milking, others consider milking prior to calving renders calving more difficult, but no definite opinion can be given.

During the summer cows may calve on the grass, but in winter

stock should be housed prior to calving. When the milking cows are brought in for nights, the down calving heifers should come in also. Such animals may be kept either in yards or boxes. The food prior to calving must be laxative. If an animal is to calve indoors, preparations should be made well in advance, and on a dairy farm at least one box should always be ready for calving. A calving box should be 12 ft. by 12 ft., well lit, well ventilated, with good floor and walls which may be cleaned and disinfected easily. A heifer or cow should be put in her calving box for several nights before calving for her to become accustomed to it. The bedding should be adequate but not excessive.

Some breeders calve all their stock in boxes in case assistance is required, but during the summer many breeders calve on grass and so lessen the risk of disease.

Several days before calving, the udder begins to become distended, and, particularly in a heifer, the teats appear waxy and tight. At about 24 hours before calving the ligaments around the tail soften, hollows appear on either side of the backbone, and the tail head is raised. A few hours before calving the cow becomes uneasy and then as the calf moves into the pelvic girdle she looses the spring of the ribs and becomes flat-sided. As calving time approaches nearer the cow strains, with her back arched, a bladder appears and breaks, and exposes the calf's forelegs. With a normal presentation the calf's forelegs and head should appear first. Repeated straining forces the head of the calf through the pelvic girdle. If assistance is given it is either to help the calf pass through the pelvis, or with mal-presentation to place the calf ready for birth. If the cowman assists the cow, he must carefully wash and disinfect his hands and pull only when the cow strains. Normally the calf is born within a few hours of the commencement of calving and the after-birth is passed out within the next 24 hours. If the after-birth is not passed naturally, a veterinary surgeon should be called in. After calving, the cow may be given a drink of about one gallon of chilled water to inhibit straining and to quench her thirst.

There is much difference of opinion regarding the time during which the calf should suckle. If removed at birth the cow never misses the calf and she settles quickly to milk production. The calf is then bucket fed and no difficulty should occur. If this system is adopted the calf must be removed immediately it is born, thoroughly dried by rubbing with wisps of straw, and given some colostrum from its own dam. When the calf is removed four days after birth both cow and calf are thoroughly upset and the cow usually withholds her milk for several days. The advantages of this procedure are that the cow licks the calf dry and in so doing massages it. This helps the circulation and the fluid imbibed by the cow acts as a mild aperient. In addition, for its first few days, the calf receives its mother's milk and consequently usually thrives better.

The feeding immediately after calving needs careful attention for no concentrates must be fed until all inflammation has left the

udder. Any inflammation may be dispersed by massaging and careful milking. Special care must be taken in milking cows after calving, for heavy milking cows if milked dry are more susceptible to milk fever. High producing cows are the most liable to suffer from the fever and it rarely occurs in heifers. The fever appears within a week after calving, when it is first detected by a peculiar staring eye, quickly followed by a staggering gait. If promptly treated the cow may recover quickly. To treat it, the udder is inflated with air and the teats are tied up. The cow is then given a drink as a stimulant and to open her bowels. If treatment is withheld, death may occur within a few hours. As prompt action is necessary, every dairy farmer should be equipped with a milk fever pump, which only costs a few shillings.

As soon as the cow has recovered from calving and the loss of her calf, she may be fed carefully for milk production. A cow usually reaches her highest milk yield within six weeks of calving. The breeder hopes to obtain the maximum yield and assumes that if she milks well at the beginning of her lactation she may maintain that high production throughout. Thus a concentrated ration is fed slightly in excess of production requirements until her maximum yield is reached. It is supposed that in this way the milk yield may be increased until the maximum is reached and the cow can then be fed accordingly. The concentrated rations for milk production vary according to prices and the individual tastes of the cows. For high milk production the palate of each cow must be carefully studied and foods given accordingly.

Examples of balanced rations for milk production are :—

	Foods	Proportions	Feed per Gallon of Milk
1.	Palm Kernel Cake ...	1	3½ lbs.
	Maize Gluten Feed ...	1	
2	Decorticated Ground Nut Cake ...	2	3½ lbs.
	Crushed Oats ...	2	
	Crushed Barley or Rice Meal ...	2	
	Crushed Wheat or Barley ...	1	
3.	Cracked Beans ...	4	3½ lbs.
	Crushed Oats ...	3	
4.	Soya Bean Cake ...	2	3½ lbs.
	Crushed Wheat ...	2	
	Rice Meal ...	2	
	Maize Germ Meal ...	1	
5.	Linseed Cake ...	1	4 lbs.
	Bran ...	1	
	Cracked Beans ...	1	
	Crushed Wheat or Barley ...	1	

In addition to the ration for milk production the cow must receive a maintenance ration. This varies according to the live weight of the cow, the food available, and the amount of milk she produces. A high producing cow may require little in addition to her concentrated foods.

Typical maintenance rations for low yielding cows weighing 11 cwt. are :—

Roughages.	Roots.	Other Foods.
1. 20 lb. Meadow hay	—	—
2. 12 ,, Meadow hay	40 lb. Mangolds	—
3. 5 ,, Lucerne hay	80 ,, Mangolds	—
4. 10 ,, Meadow hay	—	25 lb. Oat and tare silage.
5. 7 ,, Meadow hay	30 ,, Mangolds	20 ,, Oat and tare silage.
6. 14 ,, Oat straw	—	35 ,, Oat and tare silage.
7. 21 ,, Oat straw	—	2 ,, Dried sugar beet pulp. 10 ,, Wet Brewers' grains.

The above maintenance rations illustrate the diversity of feeding, but probably rations 1, 2, 4 and 5 are the best, and can be recommended.

The winter feeding may be controlled by feeding the herd, or a certain number of cows, a definite number of trusses of hay, "skips" of roots or bowls of concentrates. The summer feeding on grass is more complicated for the grass varies considerably from field to field throughout the year and also from season to season. Cows giving over five gallons of milk should graze at most only for a few hours, for they may eat too much grass and too little concentrates, with the result that their milk yield is depressed. For lower yielding cows, depending on average grass land, rationing should be on the following basis :—

April, May and June grass	=	Maintenance and $2\frac{1}{2}$ gallons of milk.
July grass	=	Maintenance and 2 gallons of milk.
August grass	=	Maintenance and $1\frac{1}{2}$ gallons of milk.
September grass	=	Maintenance and 1 gallon of milk.

There are big variations in both district and season, but the cow supplies the best information on her requirements, for if her yield drops it may be assumed the grass is not as good as anticipated, and more concentrated foods should be fed. In some districts where the grass fails, lucerne, maize, kale or cabbages are fed on the grass to provide the maintenance ration.

Usually, five months after pregnancy, there is a definite fall in a cow's milk yield. This may be so great in a poor producing cow that she becomes dry immediately, but a good producing cow may milk till her next lactation. A cow should have at least six or eight weeks dry period at the end of one lactation before the next commences. This enables her to recuperate in flesh, glandular tissues and minerals, for lactation exerts a big strain upon an animal. A cow's milk flow may be stopped by suddenly ceasing to milk her. This is quite safe if she gives no more than 15—20 lb. daily, but questionable if she is giving a greater daily yield. As

an alternative she may be milked less thoroughly daily and then only on alternate days. Whichever system is adopted, no concentrated foods should be fed till the milk flow has ceased. She may then be fed freely with concentrates to facilitate strong reserves.

Dairy cows must have large quantities of good drinking water when lactating, *e.g.*, a cow giving five gallons of milk may require 15 gallons of water daily. Ideally, all cows should be able to drink at will, but that is not always practicable.

As milk contains a high proportion of minerals a high yielding cow must receive an additional supply unless they are being obtained from grass. The easiest way of feeding these is to mix two per cent. of sterilized steam bone flour into the concentrated foods. In addition cows should always have access to salt, which may be provided in the form of blocks of rock salt

In some districts cows are milked out of doors during the summer, but generally they are milked in a milking shed. The winter management is very variable. In warm sheltered districts the cows are housed only during milking, either in a small milking shed or a portable shed holding as few as six cows. Other cows are kept in the milking shed for the entire winter, and are fed, watered and milked in the same shed. Obviously it must be well lighted, and ventilated and have a good easily cleaned floor. On other farms the cows are kept in covered or open yards except for milking. This is the ideal housing system for the cows have free movement and lie well sheltered in covered yards. The milking shed must have a good floor, but light and air are less essential than when cows live entirely in the cow shed.

Opinions differ regarding the time at which the cow manufactures her milk but it is well known that the yield obtained at a milking is greatly influenced by circumstances and by the milker. As cows are nervous animals a cowman should milk quietly, quickly, gently and thoroughly. The last drop of milk should be obtained at each milking for it contains the highest percentage of butter fat, and if allowed to remain in the udder it retards milk production. Cows may be milked by wet or dry hands or by machine, but if well done the dry hand method is preferred, wet handed milking is unnecessary and often results in dirty milk.

During the last few years the mechanism of the milking machine has been so improved that with good operators it may be used advantageously in a herd of over 30 milking cows. Although it saves labour during milking, extra time is required to wash the machine. It must not be left on a cow too long, for eventually she may give her milk too slowly, and each one must be hand stripped to obtain the last drop of milk, to massage the udder, and to see that it is quite sound.

The disadvantages of the method are that old cows may not settle to machine milking, and its use complicates milk recording, for the milk of each cow has to be kept separate until the strippings

have been obtained. In such cases the cows are usually recorded only for one day per week. Another disadvantage of the machine is that it may spread disease, but no evidence can be given to support this claim. The normal hours of milking are for twice daily, 5 a.m. and 3 p.m. and for thrice daily 5 a.m., 12 and 9 p.m.

During the last thirty years milk marketing has been completely reorganized, for instead of milk being produced in small, badly ventilated cellars in the centre of towns, it is now produced on farms possibly over a hundred miles from the consuming centres. Thus milk is required to keep sweet for a longer period. The keeping quality is largely influenced by the bacterial content, which in turn depends on the cleanliness with which the milk is produced.

Elaborate buildings are not essential for clean milk production but floors and walls which can easily be cleaned minimise the work. The shed must be well lit day and night to enable the cows to be thoroughly cleaned before milking and to discourage bacterial growth. The milkers must wash their hands before milking each cow and they must wear white overalls. All milk must be removed from the shed as soon as it is taken from the cow and cooled to 56° F. All utensils used for milk must be cleaned immediately after milking by first rinsing in cold water, then scrubbing with warm water, and finally by sterilizing with steam. They are preferably kept in a sterilizing chamber until next required. If clean milk is to be produced this sterilization of the utensils is essential. It is easily effected with an inexpensive boiler.

In laboratory tests it is found that clean milk contains comparatively few bacteria per cubic centimetre and no coliform organisms (which frequent dung), but dirty milk may contain millions of bacteria per cubic centimetre and an abundance of coliform organisms. Some purchasing firms give a bonus according to the cleanness of the milk.

A farmer may keep records of the production of his individual cows himself or through a local milk recording society. The latter course has the advantage that the records are authoritative. The milk may be weighed either at every milking in her lactation or at each milking on one day of every week. Daily recording gives the exact production record. It is thus a check upon the milk sales, and further it gives some information as to the health of the cows, for the first indication of an illness is a fall in the milk yield.

Milk recording provides the only economic means of feeding: for concentrates should be fed according to milk production. Further it assists the breeding policy, for it indicates the best cows from which to build up a future herd. Milk yields are also essential to evaluate a bull, for the milk yield of his daughters can be compared with those of their dams. Finally, milk recording increases the capital value of the herd by forming a basis for the selection of the best milkers.

Of all the factors influencing a cow's milk yield breed is the most important, *e.g.*, Hereford and Freisian. Other important factors must, however, be remembered when comparing the milk yields of cows. Lactation is aided by a long dry period before calving, by autumn calving, by delayed service after calving, and it reaches a maximum at six to seven years of age. It has been shown that the frequency of milking increases the milk yield. If a cow is changed from milking twice daily to three times daily, then she may give 10 per cent. to 20 per cent. more milk and a still further increase may be obtained by milking four times daily. The daily milk production of a cow is subject to fluctuations brought about by changes in her health, in food, and in temperature. Young spring grass, roots, brewers' grains, and possibly sugar beet pulp stimulate milk production, but old meadow grass affects it adversely.

The percentage of butter fat in milk varies considerably between individual cows and breeds, but in addition the percentage of fat in a cow's milk varies throughout her life time. The highest fat percentages are obtained when the cow is young. Towards the end of each lactation, as the milk yield falls, the fat percentage increases, but not in inverse proportion to the milk yield. Feeding may influence the fat percentage, for the sudden addition of linseed to the ration stimulates fat production, while cod liver oil and some milk stimulating foods have the opposite effect. Irrespective of the frequency of milking the lowest fat is obtained at the morning's milking. This may be exaggerated if the morning milking is later than usual, and the legal minimum of three per cent. butter fat may not be reached.

Dairy Males.—Before bull management is described, the utilization of culled bull calves may be considered. Many bull calves are sold annually for veal by dairy farmers. To obtain good veal a few general principles must be observed. Commencing with a big calf at birth, it is fed entirely on whole milk and sold when three months old, at a weight of 200—250 lb. As foods other than whole milk produce discoloured flesh, to obtain the best quality the calf must be fed with whole milk, preferably three times daily, at a maximum rate of two and a half gallons per day. If exercise is discouraged by keeping him isolated in a dark shed he should gain one pound live weight for each gallon of milk fed. Unfortunately calves are most plentiful when the milk reaches the best retail prices. Veal commands a good price at Easter.

Bull management may be divided into rearing, age to use for service, and breeding. Bull rearing is an exceedingly expensive and specialized business for the bull must be well grown to command a good selling price. A bull calf may suckle either his own dam, a foster mother, or in some cases more than one foster mother simultaneously till he is 15 months old. In addition he should receive concentrates similar to those fed to dairy heifers. He needs daily attention and handling by thoroughly grooming and exercising. The exercise may be obtained by letting him run on

grass with the cow he is suckling or by leading him by a halter on a hard road. The bull calf must be controlled completely for he may be exceedingly troublesome if not mastered. Thus when he is about six months old a light, copper ring should be passed through his nose, to facilitate handling. For a short time the nose may be tender, but after several months when it has hardened he may be tied up indoors by the ring. Then he may be led with a halter, and a staff in the ring for safety.

As with heifers so with bulls, the age to commence breeding depends largely upon the breed and the development of the bull. Usually a shorthorn bull may be used for service when 12—15 months old, provided services are limited to one per week until he is 18 months old. If no limitation is imposed the bull's breeding life may be reduced. When the bull is first used for service care must be taken to see that he is adequately fed lest his growth be impaired. No definite system can be given for it depends largely upon his condition. For successful breeding he must be in good store condition.

Frequently the bull is the most neglected and worst housed animal on the farm for he is often put into a small box, never exercised, cleaned or groomed and only taken out for service. With such treatment the bull may become bad tempered. The housing of the bull is important for he should be near the cows yet easily exercised. Good systems of housing are either a bull yard with two sections, an open concrete yard for exercise and service and a covered yard for shelter or a well fenced half-acre field with shelters. He may settle better if a cow runs with him. If the bull is kept in a box with no provision for exercise then he should be taken out for half an hour's exercise daily. This is frequently omitted. The exercise should be on a hard road to keep his hoof short. If it becomes long it must be trimmed.

As no one can forecast the real value of a young bull, he must be so managed that if necessary he may be used for breeding as long as he is fertile. This may be until he is over ten years old.

Beef Breeding Stock.—A mild climate and good grassland are the two essentials of a beef breeding farm. The breeding is arranged so that the birth of the calves coincides with the spring growth of grass. Usually the cows calve on the grassland without any assistance, where they are born healthy. The stockman must see that the calves suckle and that the cows cleanse. This may be a difficult matter for sometimes a cow eats the afterbirth or "cleansings." The sole food of the cow is grass and of the calf milk and, later, grass. When stock have access to young luscious grass in a fresh pasture, or after rain, care must be taken lest they scour or become blown. If a large quantity of grass is consumed it ferments rapidly in the rumen (stomach), the barrel becomes distended, presses on the heart and lungs and the animal may die. If the grass is suspected the stock must either be turned in only for a few hours and then transferred to other grass for most of the

day, or some supplementary foods must be given. When essential either undecorticated cotton cake or a small quantity of hay may be fed.

At the end of the summer the calves are weaned and the steers may then be sold, but the bull calves are fed and managed similiarly to dairy bulls. They may suckle till they are almost twelve months old. In sheltered districts the weaned calves may remain on grassland all the winter but in others they should be housed in yards and fed cheaply with hay, roots, and possibly concentrates. In the spring the yearling heifers should be turned out to grass again and bulled when 15 months old for it is too expensive to keep them a further year before breeding If early breeding reduces the size, it is not important for the heifer will have a six months dry period after suckling in which to recuperate and grow.

Three months after calving the bull is run with the herd, or in the case of a big herd the females may be grouped in different fields according to their ages, and a bull turned into each group. The parentage of calves will be known but the exact date of service and the subsequent calving of the cows is not recorded. This is not necessary with a beef herd where their dry period is usually about six months.

The in-calf cows and heifers receive no special feeding or management unless during the winter there is frost or snow, when they may be given, reluctantly, a little hay. This may make the cattle poor foragers. In winter with limited housing accommodation the in-calf heifers may be housed while the cows remain on grass. Large yards facilitate littering and feeding with roughages and so reduce labour costs.

The essential feature of beef breeding is to use the minimum of labour throughout the whole year.

Beef Fattening Stock.—During the last few years the beef industry has been altered by the demand for small lean joints. This change is more pronounced in the south of England than in the north. Small joints are obtained by killing the cattle for baby beef at 15 months and for mature beef at two and a half years, whereas mature beef used to be killed when four or five years old.

In this country the cattle fattened for beef are of several types and many breeds. They are derived either from the beef breeds, or by cross breeding, or they are the by-products of the dairy industry.

As only a few of the beef bull calves born will be required for breeding the majority are castrated when two or three months old and either kept and fed with the heifer calves or sold at weaning time. Castration may be effected by the common method of cutting off the bottom of the scrotum and then drawing out the testes and glandular appendages. Another method which is less liable to cause infection is to use a special castrator to crush the cord of the testis. This causes it to atrophy. To perform the

operation first place a collar round the calf's neck, throw it on its side and tie its upper hind leg to the collar. This exposes the testes. One person then holds the calf down, another manipulates the castrator and a third person locates the testes. The most important consideration is to ensure that the testis cord is crushed. Each cord in turn is pressed to the side of the scrotum and crushed by closing the castrator handles and for certainty each cord is crushed in two different places. After releasing the calf runs about little harmed but for a few days afterwards the scrotum may be swollen and the calf may be stiff in his hind legs.

The castrated bull calves may run with heifer calves not required for breeding. The steers may be sold either as stores or kept and fattened as mature beef. As each beef cow produces only one calf per annum the calf has to pay not only for its own food and labour but also for that of its mother and then leave a profit. The culled animals are usually kept for mature beef rather than baby beef because there is less chance of making a profit with the smaller animals. Store stock from breeders' farms may be sold when six months old or at subsequent six-monthly periods for either spring or autumn feeding.

It is possible to produce stock for fattening by crossing breeds : beef with either beef, dual purpose or dairy, or again dual purpose with dual purpose or dairy breeds. Thus with the many breeds of cattle in this country the possible combinations are numerous. Experience has shown that cross-bred animals frequently thrive better than either of the parent types and make bigger live weight gains. This is illustrated by the famous blue-greys, the parents of which are Galloways and Beef Shorthorns.

Most of the beef-cross animals, and those from the beef and dual purpose parents, will be sold when two and a half years old. Few will be kept for baby beef which cannot be produced economically with animals of these types. When dual purpose or dairy herds are kept for milk and crossed with a beef bull many of the progeny may be fattened for baby beef.

The cows milked in this country are dual purpose, dairy and nondescript. The bulls are varied also, thus many bull calves and poor heifers are born and eventually fattened. These animals are so numerous in some districts that they monopolize the markets. Many of these dairy by-products calves are sold when about a month old, or they may be retained for veal and baby beef production but rarely for mature beef. Calves may be purchased by rearing farmers who keep them till they are about six months old. Then at each spring and autumn, such animals are sold as stores through the local market or dealer either to graze or to eat roughages and roots in yards during the winter, and to tread down straw to dung. Finally these animals are bought when two or three years old for fattening either on grass or in yards.

Recent statistics show that many cows are culled annually from the dairy herds with udder and breeding troubles. With the dual

purpose breeds these cows may be fattened and sold for beef. A heifer when sold is as valuable as a bullock. Older cows, if well fattened, produce much suet and may be sold during the winter for over £20 each. As these cows do not command a high price the fattening costs are kept to the minimum. Usually such cows run with the herd and receive concentrated foods slightly in excess of their milk production requirements. They are quite fat when dry.

Thus it will be seen that the fattening stock for mature beef is obtained from all sources, but baby beef only from dual purpose and dairy parents. As the feeders are not the breeders many poor type stock are bred for fattening.

Various ways of feeding are required for the production of baby beef, mature beef produced in yards and mature beef produced on grassland.

Baby Beef Production.—During the last few years baby beef production has increased and stock are commonly sold fat at 15 months old weighing nine hundredweights. Such stock have no store period and for their whole lives are housed in sheds or yards. Frequently they are born, reared, and to retain their calf flesh, fattened on the same farm. Stock for baby beef production are rarely purchased except from a known source for they are required to grow and fatten simultaneously and only early, well-bred stock will do this.

Feeding for the first three months is the same as for dairy calves, but subsequently it is more liberal as shown by the table on p. 547.

During warm weather in the summer, silage or green food is essential to maintain the appetite. Whilst receiving milk, the calves need individual pens, but later labour can be reduced by putting several together in yards or boxes. The final fattening must be done in either covered yards or boxes.

Several advantages are claimed for baby beef as compared with mature beef. These are (1) the store period is eliminated ; (2) by selling at an early age capital is more frequently turned over, so increasing the chance of profit ; (3) if the prices are bad, baby beef stock may be held for a time, but mature beef must be sold when fat, irrespective of prices ; (4) the stock may be sold between the marketing of grass fed and yard fed beef and so command good prices ; (5) baby beef produces the popular small joints.

On the other hand the disadvantages of the system are : (1) higher labour cost ; (2) higher demand for concentrated foods ; (3) difficulty of utilizing coarse fodders ; (4) difficulty of finding labour for summer stock feeding ; (5) soiling or silage crops must be grown to keep them feeding ; (6) the meat is said to be bony and of poor colour ; (7) some animals grow and will not fatten.

Because of these difficulties some stock may have to be sold as beeflings when 18 to 24 months old.

DAILY RATIONS FOR BABY BEEF PRODUCTION.

Age in Months.	Live Weight of Animal in cwt.	Concentrated Foods Fed.	Roughages Fed.	Succulents Fed.
3	¾ to 1¼	As for dairy calves	As for dairy calves	
6	3¼	1 part linseed cake, 1 part crushed oats, 1 part cracked maize } 4—5 lb.	5 lb. good meadow or seeds hay	10 lb. roots or 5 lb. silage
9	4½ to 5	1 part decorticated ground nut cake ... ..., 3 parts crushed cereals ... } 4 lb. Dried sugar beet pulp moistened 2 lb.	7 lb. medium quality hay	20 lb. roots or 10 lb. silage
12	6½ to 7	1 part decorticated ground nut cake or cotton seed meal ... ..., 1 part bean meal ... ... } 6—12 lb. 3—4 parts crushed cereals.	8—10 lb. medium quality hay	30 lb. roots or 15 lb. silage
15	8½ to 9	Above mixture 7—10 lb.	8—10 lb. medium quality hay	40 lb. roots or 20 lb. silage

DAILY RATIONS FOR MATURE BEEF PRODUCTION.

Age in Months.	Live Weight of Animal in cwt.	Concentrated Foods fed.	Roughages Fed.	Succulents Fed.
3	¾ to 1¼	Milk only	Grass	Grass
6	4	1 part decorticated ground nut cake ... ... 1 part crushed barley ... } 2—3 lb.	5 lb. medium meadow hay *or* Grass	15 lb. roots or 5—10 lb. silage *or* Grass
12	5 to 6	1—2 lb. undecorticated cotton cake in the spring	Grass	Grass
18	7 to 8	1 part cotton seed meal 1 part crushed cereals } 2 lb. *or* Grass	10—14 lb. poor hay 10—14 lb. straw *or* Grass	40—100 lb. roots *or* Grass
24	9	3 parts crushed wheat, barley or oats ... ... 3 parts Rice meal ... 1 part ground nut meal ... } 6—12 lb. 2·4 lb. linseed cake in addition for final 2 months *or* Grass	7—14 lb. medium hay 3 lb. oat straw or chaff *or* Grass	40—170 lb. roots *or* 20 lb. silage *or* Grass
30—36	9 to 10	Grass	Grass	Grass

Yard Fattened Bullocks.—Arable farms produce large quantities of roughages and roots for which there is no sale. These foods may be efficiently utilized by bullocks. Bullock fattening has been very popular, but of late it has been less profitable than dairy production, and on some farms bullocks have been replaced by cows. In addition, on arable land large quantities of straw must be converted into farmyard manure, and bullocks have been the medium employed. All of the corn can rarely be sold off the farm and the tail corn left may be fed to cattle. As the feeding is to utilize bye-products they may be fed liberally and purchased foods so reduced to the minimum.

When feeding bulky foods the yards must be arranged to save labour. All yards should be in direct communication with the food supplies, preferably by a covered passage. Each yard should be large enough to hold 10 to 20 bullocks. The bullocks may be sold fat any time after Christmas, but mostly in February, when weighing about 12 cwt.

Grass Fattened Bullocks.—On the best grassland of this country it is possible to fatten a bullock in 16 weeks without any concentrated feeding, and to gain two pounds weight daily. Such grassland is usually stocked in April with large bullocks at least two-and-a-half years old. The graziers state they must have old animals for they make better live weight gains, fatten more easily and suffer less from scouring. Experience has shown that younger animals scour very badly and need concentrates to be fattened. Thus large old steers are purchased which are difficult to sell when fat. Such land is really only suitable for fattening old stock, and unless supplementary foods are fed it should not be used for younger stock.

Killing percentage.—No account of meat production would be complete unless some mention was made of the killing percentage of cattle, for it is of great importance to the butcher who buys cattle on their live weights. The killing percentage of an animal is obtained after taking its dead weight, after the intestines, liver, heart, lungs, skin, head, feet and tail have been removed as a fraction of its live weight. The loss of weight is influenced largely by the contents of the intestines. Butchers prefer to kill bullocks after about 48 hours fasting, and such animals kill a high percentage if weighed just before killing.

A well-fattened bullock kills a high percentage, for he has a high proportion of flesh to offal. Usually a young bullock does not kill as well as an equally well fleshed older animal, for the younger bullock has a higher proportion of intestines.

An average killing percentage is 56 per cent. but it may easily exceed 60 per cent. or even 70 per cent. in a well finished bullock fasted before killing, but a poor bullock may kill under 50 per cent.

CHAPTER XXII.

SHEEP: THEIR MANAGEMENT AND BREEDS

SHEEP have always played a very important part in British Agriculture. Famous for their wool, for which in the form of cloth there was always a ready market abroad, they laid the foundations of our prosperity as an industrial nation. Sheep are no longer kept in this country principally for their wool, but for their mutton, wool being but a secondary consideration.

To-day there are various systems of keeping sheep, where formerly there was but one, the extensive system. With the introduction of the root crop into British agriculture other systems became possible and the sheep became a factor in the economy of the ploughland farm.

It is possible to distinguish three systems under which sheep are managed, though we must bear in mind that there are no hard and fast divisions between one system and another.

MOUNTAIN SHEPHERDING.—This is an extensive method. Large flocks of small, hardy, active breeding ewes are kept on unfenced moor and mountain, subsisting under very adverse conditions of soil, climate and altitude, and receiving little food beyond what they can pick up, except in severe weather. Such ewes produce a 4 lb. fleece of wool, and about 90 per cent. of weaned lambs. From the nature of the case lambing is late, and does not start before April or May. With the exception of those required for breeding purposes these lambs are mostly sold as stores, to be fattened elsewhere, under more kindly conditions, and are fed off at a comparatively early age. When wool was more valuable than it is to-day these lambs were often kept until they were two or three years old, for the sake of their wool, and were eventually fattened off as mature animals on the hill itself. Mutton of this type was very highly esteemed. The regular draft ewes from these hill flocks are sold for crossing purposes on the lower and better farms, and after one or two crops of cross-bred lambs have been taken from them they are fattened off.

GRASSLAND SHEPHERDING.—This consists usually in breeding, but sometimes in feeding as well. A flock of one of the large, long-woolled types of ewe is either crossed or bred pure. The ewes are kept on grass all the year round. In the winter they are spread very thinly over the pastures, and are fed hay in addition if the grass is scarce and weather severe. Lambing takes place in the open fields towards the end of March and in April. There is little advantage in having lambs before the advent of grass. The lambs may be simply run on as stores and sold for fattening as tegs or hoggets on turnips, or may be fattened off as lambs straight from the ewe. The latter method entails, as a rule, feeding a liberal allowance of cake and corn to the lambs through creeps.

On the best grassland a certain amount of buying in of store

sheep in the spring is practised, the sheep being fattened out during the summer as shearlings. It may be noted here that in order to get the maximum amount of grazing from pasture land a mixed stocking is desirable, cattle, sheep and perhaps a very few horses. It is certain that the minimum amount is obtained when the stock consist exclusively of sheep. The best proportion of cattle to sheep varies from farm to farm, and can only be decided by the individual farmer. Grassland sheep have undoubtedly been gaining ground for the past few years, and there is a steady and increasing migration each year of sheep of this type from Scotland and the north of England to the eastern and south eastern counties.

PLOUGHLAND SHEPHERDING.—This type of shepherding often consists simply of buying in store sheep bred under grassland conditions, and fattening them out on roots in the winter. It may also consist of breeding, one of the short-woolled Down breeds being usually employed. Lambing is generally early, and if the production of fat lambs is aimed at, will start about Christmas In any case it is rarely delayed after the end of February. The lambs are either sold fat early in the season, or they may be retained as stores either for sale for fattening elsewhere, or more often for fattening as hoggets during the winter on the farm on which they were bred. Of late years, owing to the high cost of labour and the consequent decline of root growing, ploughland shepherding, particularly the maintaining of breeding flocks, has become less popular. Apart from the production of early fat lambs (which are a luxury and for which a luxury price must be obtained if they are to be profitable), and pure-bred flocks kept for ram breeding, it would seem difficult to justify the maintenance of such a flock at the present time.

MANAGEMENT OF A BREEDING FLOCK OF DOWN SHEEP UNDER PLOUGHLAND CONDITIONS

Where a breeding flock is maintained on an arable farm the farmer has to look well ahead in order to secure a succession of appropriate folding crops, and he has to decide a considerable time beforehand where each section of the flock is to be located at any given period. Even the site of hayricks and cornstacks is often determined with a view to affording a convenient supply of hay and straw at lambing time, with as little carting as possible. On such a farm the shepherd plays an important part, and much will depend upon him. He must therefore be a well qualified man of sound experience, intelligent, thoughtful and methodical.

From the point of view of the management of the flock, the year divides itself into three periods.

3 months : the flock empty.
5 months : the flock in lamb.
4 months : the flock suckling their lambs.

The first period commences as soon as the lambs are weaned.

Weaning is done at various ages from 8 to 16 weeks, depending on a variety of circumstances, the former perhaps with lambs not dropped until late in April, for by June and July there will be an abundant supply of suitable food available on which to wean them. With lambs dropped in January or February this is obviously impossible. Fat lambs are not weaned at all but are sold straight off the ewe.

Under ploughland conditions weaning is done gradually through creeps. The lambs at a very early age are encouraged to pass through " creeps " or " lamb hurdles " into the fold ahead of their dams. Here they pick over the best of the keep, and are fed cake and corn in addition. As weaning approaches they may be shut away from their dams for longer and longer periods. With grassland flocks weaning is more difficult as creeps are not used. When the lambs are separated it is advisable at first to remove them out of earshot of the ewes. The lambs will be put on to some first-class keep which has been specially reserved for them. A fold of clean sainfoin is perhaps the ideal. The ewes will be given a scanty fold, or put on some bare pastures. During this period the flock is unproductive, and may be fed on a maintenance ration only, the ewe flock at this time being one of the very few instances where such a ration should be employed. The aim of the flock-master will be to maintain the ewes as cheaply at this time as possible consistent with keeping them healthy.

As soon as the lambs are weaned the flock will probably be " culled," that is those ewes which it is considered would be unprofitable to retain in the flock for another year will be withdrawn. Ewes may be culled for a variety of reasons such as lost quarters, broken mouths, sterility, poor milking qualities, etc. In some flocks all ewes which have reached a certain age (having had three or four crops of lambs) are withdrawn. If sound, these ewes will not be " culls," but will be " regular draft " ewes, and may be sold for breeding purposes to those who keep " flying " flocks. The culls on the other hand are not suitable for breeding and will either be fattened off by the flock-master himself or sold for someone else to fatten.

This is an opportune time to go through the flock for signs of foot rot. On some farms the complaint is very troublesome, and it is wise in such cases to treat the ewes systematically at frequent intervals to prevent an outbreak. Treatment should never be left until the sheep are lame. As a preventative, the sheep may be put through a foot bath of copper sulphate at intervals. Any suspected sheep should be caught and their feet pared and dressed.

Shearling ewes are bought in annually to take the place of the culls. These shearling ewes will thus be two years old when they produce their first lambs. Breeding from ewe lambs is unusual and is not recommended. If practised it is essential that they should be well fed during the whole of the winter, that they should

not be mated to the ram too early in the season, and that the ram chosen should be of some small breed, such as the Southdown.

The gestation period in a ewe is roughly 154 days. The date of "tupping" (the mating of the ewes to the ram or tup) will vary. If early fat lamb is aimed at the ram may be turned in in August, by which date a great many of the ewes of Down breeds will have started coming into season. On the other hand with grassland breeds tupping may not start until November, the ewes lambing in April. Indeed it is doubtful if ewes of grassland breeds could be mated in August, even if desired, as ewes of this type do not as a rule come into season until later.

Before the ewes are put to the ram they are "flushed." This simply means that their food is improved, the aim being to get the ewes into good and improving condition when put to the ram. If this is done the ewes come to the ram quicker and so the period of lambing is reduced, conception is more likely to take place, and the proportion of twin lambs will be increased.

This flushing may be done by bringing the ewes into a fold of some succulent fodder crop which has been grown or saved specially for the purpose, or on to some good grassland not previously sheeped that season.

The ram is half the flock, and a breeder must always be a buyer of rams even though he be a ram breeder himself. Such a man, however, will always use a good proportion of his own home bred rams. Uniformity in a flock, or flock type, is very desirable, and can scarcely be achieved without some degree of inbreeding. The utmost care must be taken in the selection of the ram as to health, constitution and conformation. It is wise to prefer quality to size. Buying one with a blatant fault common to that particular breed should be avoided. The flock-master should always aim at buying a ram better than the ewes to which he is to be mated. The following points are important and apply to all breeds :—

Bold masculine head, with thick muscular neck and pole, wide forehead, full eye and broad nostril. Body level and square, well ribbed up, and showing great length, straight broad back, chest wide ; well covered all over with the characteristic wool of the breed. In addition the ram must be active and sound. Although, as has already been said, it is unusual and as a rule inadvisable to breed from ewe lambs, this is not so in the case of rams. With the early maturing down breeds, ram lambs are preferred to old sheep.

Where possible it is preferable at this time to divide the flock up into small lots, turning in a single ram with an appropriate number of ewes. In this way each ram will serve from 40 to 60 ewes according to the age and breed, whereas when all the flock are together not more than 30 to 50 ewes per ram would be considered safe. When the ram is turned in he is coloured on the breast, so that any ewe he serves is marked. In this way a check is kept on the number of ewes that are being served. All ewes should be

marked by the ram within 28 days. At the end of this time the colour put on the ram is changed so that it may be seen if many ewes are returning, and the ewes which will lamb later than the rest can be identified.

As soon as the ewes are clear of the ram they should be overhauled for foot rot once again. During the five months of pregnancy the aim should be to keep the ewes in good healthy condition, neither getting them fat nor allowing them to become thin and weak. They need constant watching, any carelessness possibly being reflected in lambing weeks later.

It is most important that the flock at this time should have plenty of dry food, and should never be allowed to gorge themselves with roots. It is the general experience that a good root year is followed by a bad lambing. The ewes are best when given plenty of run on old seed leys and pastures, and roots if fed should be limited in quantity and dry food given in addition. Frozen roots should never be fed. Pregnant ewes should never be grazed on unsound land in late summer or autumn, but may be perfectly safe on the same land in the spring and early summer. Thus water meadows afford a good and safe feed for ewes and lambs from March to May, but should not even be walked over late in the season.

The shearling ewes will need careful watching, and may require more liberal treatment than the older sheep as pregnancy advances, and certainly when suckling.

The flock should have somewhere dry to lie. Cold weather does not hurt them but prolonged wet may, and during very wet weather they should be withdrawn from the arable land and laid on grass. Trough feeding of in-lamb ewes is to be avoided if possible, but if it be necessary it should be commenced in good time, for to regain condition once it is lost at this time is very expensive at best, and is not always possible. There must be plenty of troughs and food must be given with regularity. Suitable foods are oats, bran, beans, and dried grains. In-lamb ewes should never be allowed to become ravenously hungry, nor should they be dogged or over driven.

The quantities of food consumed by a flock of in-lamb ewes of one of the Down breeds will be roughly from half to three quarters of a load of roots per 100 per diem together with dry food which may start by being oat and pea straw fed at the rate of ½ to ¾ cwt. per 100 ewes daily, and will be gradually replaced by hay as pregnancy advances. If necessary half a pound of concentrated food per head per day may be fed in the last month of pregnancy. The ewes should not require cake or corn for eight months of the year, the time when money may be most profitably spent on concentrates for them is when they are suckling lambs.

In some districts it is the custom to run ewes thinly on grassland up to Christmas, bringing them on to the roots when lambing commences. In such cases, if hard weather is experienced before

the end of the year, a little hay and a few roots may be given on the pasture.

Lambing is the time of heaviest mortality, but the troubles have generally been contracted earlier. Losses of five per cent. of the ewes are quite the rule and are viewed with complacency. With ploughland and grassland flocks this need not and should not be.

With the mountain breeds lambing is late, but apart from bringing the ewes into sheltered spots, and getting round them as often as possible there is little that can be done. Again under typical grassland conditions, with lambing in March and April, little is done. A few thatched hurdles will be scattered about the fields to provide shelter. Of course the shepherd under these conditions is able to give the ewes far more attention than is possible under mountain conditions. Any bad cases are confined in pens. Moreover the ewes are fed if the grass is backward.

Under ploughland conditions, with lambing in January and February, more elaborate preparations are essential. Shelter of some sort is imperative, and a temporary lambing yard built with straw and hurdles is universally adopted. Around the inside of the enclosure small coops or compartments are hurdled off. The shepherd will remain night and day with his flock during this time, and a hut will be provided for him with stove and firing. The shepherd brings all forward ewes into the lambing yard at night. As soon as a lamb is born, it and its dam will be removed into one of the coops, and there remain for three to four days until the lamb is able to follow its mother without difficulty and until they know each other thoroughly. In the lambing yard the ewes receive some cake and corn, with roots and hay. After two or three days in the coops the ewes and lambs will be transferred into one of the bigger yards of the lambing pen, and from thence out into the open fold at from four to seven days old, depending on the weather and the strength of the lamb. The ewes suckling singles and those with twins are usually kept apart from now onwards, the latter requiring more generous treatment. Cold driving rain is the severest weather for lambs. At an early age they should be encouraged to run forward through creeps in the hurdles, and to nibble the young shoots of turnip tops, etc., and eat a little special cake and corn provided for them in small troughs.

Fecundity varies with the breed, as well as with other conditions. One hundred and fifty per cent. (reckoned on the number of ewes originally mated with the ram, and thus including any losses sustained during the five months of pregnancy, as well as any barren sheep) is very good indeed, and one hundred per cent. with a Down flock is poor. On the other hand under mountain conditions one hundred per cent. would be above the average.

Feeding of Suckling Ewes.—The feeding of the suckling ewes must be generous in order to encourage milk production. They will probably be folded at first on swedes, thousand-headed kale

and kohl rabi, later on turnip tops and rape kale. The basis of the feeding will be roughly a ton a day of this sort of material per 100 ewes, together with about 1 cwt. of good hay. In addition the ewes may have some cake or corn, particularly those with twins. Creeps for the lambs are now a necessity, and the lambs are fed the very best of cake and corn, such things as linseed cake, locust beans, peas, malt culms, bran, flaked maize, and good heavy oats being much used. Rock salt should be available at all times. If the lambs are being forced they will often be given two folds a day of two different crops, and perhaps a run out on to an early piece of grass as well. In arable districts change of food is much relied upon to bring on the lambs rapidly, particularly ram lambs for breeding purposes.

As spring advances the hay may be discontinued, and after the roots are finished perhaps a piece of rye which has been specially sown early the previous autumn will be available. This, together with mangolds, which have been set on one side for this purpose, will tide over a very difficult period between the end of the roots and the beginning of the seeds. Following this, such crops as oats and vetches, sainfoin, rye grass and trefoil, and other seed mixtures will be folded. When about three or four months old the lambs will be weaned as has already been described, with the exception of fat lambs which will go to market direct from their mothers.

Under grassland conditions, where the lambs are not usually forced as on roots, only a little hay and a few mangolds will be fed to the suckling ewes, except, of course, in late seasons and when the weather is severe. Cake and corn may or may not be fed to lambs from these ewes.

In practice, numerous modifications occur of the method which has been described, but the general principles are similar in all cases. A forcing diet is given when mutton and lamb is the immediate object, and merely a maintenance diet, save at certain periods, to the section of the flock kept for breeding purposes.

Docking is more necessary for lowland than for hill flocks. Long tails mean filth, discomfort, and much damage from "fly" with lowland flocks. Docking is best done at a very early age with both ewes and rams alike. The tails may be simply cut with a knife, or seared off with a hot iron. The latter method being cleaner and causing no loss of blood is to be preferred. The dock should not be left too long, nor cut too short, about three joints from the rump being the correct length.

Castration should be done when the lambs are quite young, and before the flies get troublesome. Castration and tailing are commonly done together when the lambs are a week or so old. Genial weather without frosts at night is desirable.

Washing may or may not be carried out. It consists of rinsing the sheep in clean cold water. The sheep are dropped into a stream, soused for a minute or two, and put on some clean grassland to dry afterwards. Enormous quantities of dirt are picked up by the

fleeces of sheep folded on ploughland in the winter. The loss of weight in the fleece as the result of washing may be up to 35 per cent. so that the price of washed wool must be considerably higher than unwashed to compensate for this loss and to pay for the operation. Unfortunately the " yolk " (*i.e.*, the grease) is washed out from the fleeces as well as the dirt, and an opportunity must be given for this to rise again before shearing. Hence washing takes place from 10 to 20 days before shearing.

The date when shearing takes place depends a great deal on locality. The majority of sheep are shorn in May and June. Formerly shearing was entirely effected by hand shears, but is now very extensively done by sheep-shearing machines. The hand shear is still used among small flocks.

Dipping is now compulsory by an order of the Ministry of Agriculture, in order to prevent sheep scab, a disease caused by a mite. It also destroys such pests as ticks, lice and keds, and in some degree helps to keep away fly. It is a simple operation by reason of the convenient swim baths that are made. The best time to dip is as soon after shearing as the wool will hold the dip. Each sheep is immersed for a minute. The sheep should be cool and rested before dipping. A second dipping is frequently practised later in the season, though in certain counties a second dipping at a short interval is compulsory. Sheep dips are poisonous preparations, arsenic being the basis of the majority, with sulphur, soap, soda, lime, and mineral oils in addition.

Fattening Sheep on Roots.—Many farmers who do not themselves keep a breeding flock require sheep to fold off their roots during the winter. These sheep are frequently purchased as store lambs at the big lamb sales held during the summer and autumn. " Fresh " or forward lambs which can be got fat by Christmas are sometimes purchased, and these are followed by a second lot which will be kept till the spring. In other cases more backward sheep will be chosen, and will be brought on slowly. The feeding differs with the condition of the lambs and the intention of the feeder. As a rough generalization it may be said that a fattening sheep will receive from 10 to 20 lb. of roots, ½ to ¾ lb. of hay, and from ½ to 1 lb. per day of concentrated food, the concentrates being increased progressively as the sheep become fatter. These concentrates will consist largely of starchy foods such as cereals, together with about 25 per cent. of some protein-rich cake. The rate at which the sheep fatten depends largely upon the attention and management they receive. Regularity of feeding is most important, as is also the comfort and well-being of the sheep After heavy rain when the fold is wet and muddy the sheep should be removed and laid on grass or an old seeds ley. The sheep will probably be folded on swedes after Christmas, and these should be ground for them. As long as the sheep are folding white turnips and marrow stem kale, they can fend for themselves, but after Christmas

when the tegs are losing their milk teeth the roots fed to them should be sliced if it is desired to fatten them rapidly.

The Breeds of Sheep.—Sheep are of all animals especially influenced by their environment, hence the large number of pure breeds recognized in this country.

These breeds may be classified in various ways such as Mountain and Lowland, Longwool and Shortwool, Blackfaced and Whitefaced, Horned and Hornless. We prefer to divide into three groups corresponding with three types of shepherding, viz., Mountain and Moorland breeds, Grassland breeds or Lowland long-wools, and short-woolled breeds which include all the Down breeds.

As at the present time in this country mutton is always the primary consideration, it may be convenient before describing each breed individually to mention the points and characteristics desirable in sheep kept principally as mutton producers.

The following description is taken from "British Breeds of Live Stock," published by The Ministry of Agriculture and Fisheries.

(1) A wide, deep body, compact and well balanced, with an easy graceful carriage.

(2) A well-carried head, characteristic of the breed, with good depth and strength of jaw, broad across the bridge of the nose ; full, bold, bright eyes, indicating both docility and courage. In a ram the head must be thoroughly masculine in character though not coarse ; in a ewe it should be more refined but not weak.

(3) The neck thick towards the trunk, fitting well and evenly into the shoulders so that the junction is almost imperceptible, tapering to the head, arching slightly, medium in length, and free from "throatiness" at the junction with the head.

(4) The chest broad, deep, and projecting well in front of the forelegs.

(5) The back level and broad throughout its length (though some of the mountain breeds have sharp shoulder-tops or withers), with an even covering of firm and muscular flesh ; under and upper lines straight.

(6) The ribs well sprung and deep.

(7) The shoulders well laid and covered with firm flesh. The regions immediately behind the shoulders level and free from hollows.

(8) The thighs and also the arms and the fore flanks, thick and fleshed well down.

(9) The quarters long, deep, and wide, not drooping much towards the tail ; little space between them and the last ribs.

(10) The legs straight, set wide apart, and not too long ; the bone clean and fine, neither coarse nor deficient.

(11) Feet fairly large, sound and hard ; pasterns strong.

(12) The characteristic wool of the particular breed to be of good quality and to cover the whole body well and evenly.

Mountain Breeds.—The outstanding characteristics of economic importance in this type of sheep are hardiness and ability to thrive under adverse conditions. The sheep are small in size, extremely active, and their mutton is of the highest quality. The majority of mountain breeds are horned, though the horn is confined to the ram in certain breeds. As a rule the wool is coarse. The ewes are not very prolific, but high fecundity is hardly to be expected in a sheep which has to live on scanty grazing.

The chief mountain breeds recognized in this country are :—

Scotch Blackface	Lonk	Exmoor
Cheviot	Welsh Mountain	Kerry Hill
Herdwick	Dartmoor	

Scotch Blackface.—This breed, as far as numbers is concerned, is one of the most important in the British Isles. It occupies almost exclusively all the higher grazings of Scotland, and is found in large numbers in the counties of Northumberland, Cumberland, Yorkshire and Lancashire. Its origin is uncertain, but it seems probable that it found its way into Scotland from the north of England. The chief characteristics of the sheep are great hardiness and the fine quality of the mutton.

The face and legs should be black or mottled, smooth and glossy. Both ewes and rams are horned, and the ram's horns should be large, not joined at the base, but springing level from the crown, and the spirals should circle the short ears. The tail only reaches to the hocks, and it is therefore not necessary to dock it. (Plate IX., 1.)

The wool is a unique product. It is now used almost entirely by the carpet trade, and large quantities are exported to America. The fleece weighs on an average 3½ to 4½ lb. for ewes. It is wavy, loose and shaggy, nearly touching the ground.

The draft ewes from hill flocks are purchased for crossing purposes. The Border Leicester ram is much in favour for this purpose, and the cross combines the size and mutton production of the sire with the quality and hardiness of the dam. In the north of England these draft ewes are frequently mated with Wensleydale rams to produce what are known as "Mashams."

Cheviot.—These white-faced sheep are native to the Cheviot Hills, though they have spread over most of Scotland and a good deal of England. They thrive best on grassy uplands and in Scotland are kept on the green hills, whereas the Scotch Blackface occupy the higher and heathery hills. For symmetry they are unequalled, being perhaps the most beautiful and aristocratic looking of all breeds ; both ewes and rams should be hornless though horns sometimes occur in the ram. The wool is of medium quality and fineness and the fleece averages about 4½ lb.

Cheviots come next to the Blackfaces in their ability to subsist on the scantiest fare ; they can live through the severest winter without any artificial food, though when there is any depth of snow

hay should be given. When taken to lower and better land the Cheviot grows larger and will fatten rapidly. In these days most of the lambs, with the exception of those required for breeding, are fed off within the year, many of them being sold to arable farmers to fatten on roots. For this purpose they are docked close. The draft ewes from hill flocks sell readily to Lowland farmers for crossing purposes. They are mated with Border Leicester rams to produce the far-famed " Half-Bred " of the North Country.

These " half-breds " are in great demand for breeding purposes all over England and as grassland sheep have few equals. They are hardy and vigorous, thriving amazingly under the improved conditions. They are very prolific and good mothers. When mated to Suffolk or Oxford Down rams they produce lambs which can either be fattened as lambs on the grass or folded on roots in the winter.

It is interesting to note that these half-bred sheep breed fairly true to type when mated together, though the first cross is reckoned to be hardier. (Plate IX., 2.)

HERDWICK.—This extremely hardy breed thrives upon the poor mountain land in Cumberland, Westmoreland and N. Lancashire. The rams are horned, but ewes are hornless. The wool is strong, coarse, and open, and inclined to be hairy about the neck. The mutton is of very high repute.

LONK.—These sheep are found chiefly in N.E. Lancashire, and S.W. Yorkshire. They do well in these districts of high rainfall, for being hardy and close-coated they can withstand the weather.

They are not unlike the Scotch Blackface, but are larger with larger bodies, bigger heads, and longer legs. They yield a carcass of exceptionally lean mutton. For a mountain breed they are prolific. Attempts have been made to increase the size of the Scotch Blackface and improve its wool by crossing with Lonks but without success, the cross always resulting in a loss of constitution.

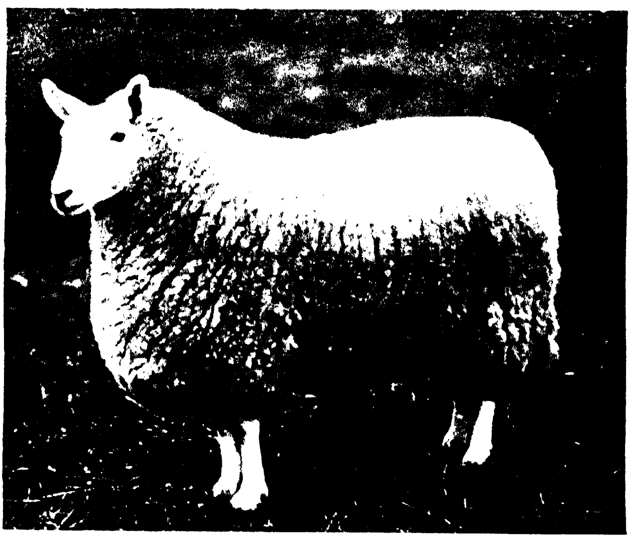
WELSH MOUNTAIN.—On the Welsh hills this small, hardy, active breed has probably remained unaltered for centuries. The face and legs are white or slightly tan ; the rams possess curled horns, while the ewes are hornless. The wool is white, short, fine and thick. The mutton is of the highest quality. The draft ewes are frequently mated with Southdown, Shropshire, Kerry Hill, or Ryland rams. Unfortunately the sheep are naturally so active and restless that few fences can restrain them. (Plate IX., 3.)

DARTMOOR.—This ancient hornless breed is practically restricted to the district from which its name is taken. It is the largest of our hill or moorland sheep, and more nearly resembles the grassland Longwool type. It owes many of its qualities to an infusion of Leicester blood.

EXMOOR.—The Exmoor Horn or Porlock Moorland sheep are probably direct descendants of the old forest breeds of that part of England. They have white faces and legs and black nostrils, and

PLATE IX.

1. Black-Face Mountain Ram.



2. Cheviot Ewe.

PLATE IX. *continued.*

3. WELSH RAM.

4. LEICESTER SHEARLING RAM

are horned. The wool is short and the fleece is close and fine. They are hardy and well adapted to the poverty of their natural pastures.

KERRY HILL.—The Kerry Hill sheep of the present day can be regarded as a hill sheep, being active and hardy, and yielding mutton of first-rate quality. In size it approximates to the Lowland long-woolled type.

Originally the breed was confined to a twenty-mile radius of the village from which it derives its name—Kerry, Montgomeryshire. But since the establishing of the Flock Book Society in 1894, the breed has increased largely in popularity, and flocks may now be found not only in Montgomeryshire and Radnorshire, but also in Cardiganshire, Breconshire, Denbighshire, Carmarthenshire, Shropshire, Cheshire, Herefordshire, Worcestershire and elsewhere.

The chief characteristics of the breed are a speckled face and legs, full length tail, compact body with light fleece, combining a first-rate quality of wool and a clean pink skin. The ewes are very prolific and extraordinary sucklers, and in addition the sheep grow and thrive rapidly when taken to better pastures. The drafts are usually bought by farmers in the Midlands and western counties for the production of fat lambs, and are considered one of the best breeds obtainable for the purpose.

Grassland Breeds, or Lowland Longwools.—While this type of sheep is as a rule associated with grassland, they are not absolutely confined to it, in fact at the present time such a breed as the Lincoln is kept largely on arable land.

They are, however, associated with abundant supplies of food, either in districts where the soil is good, or in arable districts where the food supply is plentiful.

They are all large sheep, without horns, and with heavy fleeces of long wool, usually of the "lustre" type. The face and legs are generally white. The sheep are quick growers and fatten readily, but the carcass is too large and too fat to be popular. In addition, the mutton is coarse in texture and poor in flavour.

All these long-woolled breeds have been at some time or another improved by crossing with the English Leicester.

The chief long-woolled breeds recognized in this country are :—

Leicester	Lincoln	South Devon
Border Leicester	Kent or Romney Marsh	Devon Longwool
Cotswold	Wensleydale	Roscommon

THE LEICESTER.—This breed of sheep is always associated with the name of that master breeder, Robert Bakewell of Dishley in Leicestershire. It was the first breed to be improved by systematic selection within the breed, and by in-and-in breeding, to fix the desired type once it had been secured. Starting in the year 1755 with a large, coarse, ungainly and slow growing type, Bakewell evolved a sheep of moderate size, neat, compact, and early maturing, with an amazing aptitude to fatten. He was assisted in his efforts

by the extension of the cultivation of the turnip as a field crop, which provided a liberal supply of winter food. Bakewell originated the system of ram letting. This not only gave him a greater number of rams to select from for his own use, but ensured that the rams he used in his own flock were proven sires of the type of sheep at which he was aiming.

The fame of the Dishley Leicesters rapidly spread and practically everyone of the long-woolled breeds was at some time or another improved by the introduction of Leicester blood.

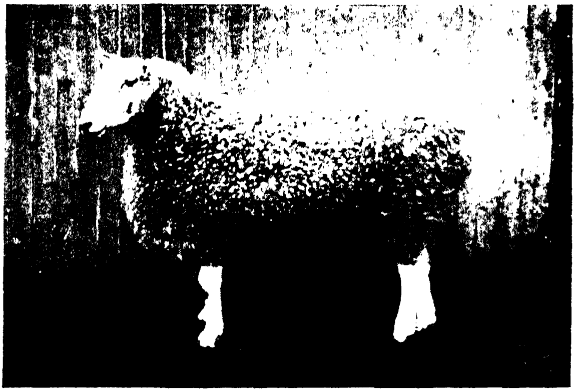
The rams of this breed are still used to a considerable extent for crossing purposes, but as a pure breed it is rather too large and fat for modern requirements, though many commercial flocks are still kept in the North of England. The following is the official description of the English Leicester : "Lips and nostrils black ; nose slightly narrow and Roman, but the general form of the face is wedge-shaped, and it is covered with short, white hairs ; forehead covered with wool ; no vestige of horns ; the ears (sometimes white) thin, long, and mobile, a black speck on ears and face not uncommon ; a good eye, neck short and level with back, thick and tapering from skull to bosom ; breast deep, wide and prominent ; shoulders somewhat upright and wide over the tops ; great thickness from blade to blade, and through the heart, well filled up behind the shoulders, giving a great girth ; well sprung ribs, wide loins, level hips, straight and long quarters ; tail well set on, good legs of mutton, great depth of carcass, fine bone, a fine curly lustrous fleece (the sheep are well-woolled all over) free from black hairs, with firm flesh, springy pelt, and pink skin. The general form of the carcass is square or rectangular ; legs well set on, straight hocks, good pasterns and neat feet." (Plate IX., 4.)

Border Leicester.—These sheep have long held a prominent place for crossing with the slower fattening and smaller breeds, such as the Scotch Blackface and Cheviot, the produce of which by Border Leicester rams, gives so desirable a sheep. George and Matthew Culley, pupils of Robert Bakewell of Dishley, brought his improved Leicesters to Northumberland about the year 1767, from whence they spread into other Border counties. They received the distinctive name of Border Leicester about 1869, when they became recognized as a different and distinct breed

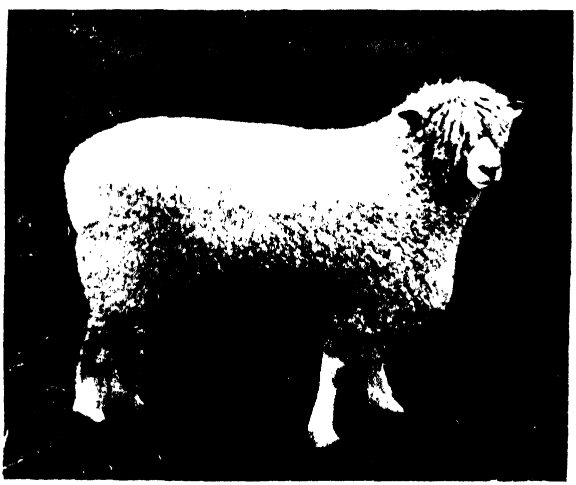
The Border Leicester is a large white-faced sheep with a clean head, and Roman nose, fleece white and lustrous, with small staple and tight curl. The wool is short for a long-woolled breed. The carcass is very fat and of poor quality. The breed is first and foremost a ram producing breed, many thousands of rams being sold annually, 90 per cent. of which are used for crossing purposes. (Plate X., 1.)

For crossing the ram is ideal, for although a large sheep it is fine boned and light in the head, and therefore may be mated safely to small ewes without fear of trouble resulting at lambing. It transmits its early maturing quality to all its crosses.

PLATE X.



1. Border Leicester Ram.



2. Cotswold Ram.

PLATE X.—*continued.*

3. LINCOLN TWO-SHEAR RAM.

4. ROMNEY MARSH RAM.

COTSWOLD.—This large and handsome Gloucestershire breed can definitely be traced back to the early part of the fourteenth century, and it has played an important part in the history of the English wool trade. Over a century ago it was improved by the introduction of Leicester blood.

It is a very big white-faced sheep, with a characteristic bold, upstanding carriage. The sheep is very adaptable and thrives well when folded on wet and heavy land. The carcass is very fat and rather coarse in quality. (Plate X., 2.)

It crosses well with many of the Down breeds, and it is largely owing to this fact that it has almost disappeared from its own district having been displaced by the Oxford Down, which originated by crossing Cotswolds and Hampshire Downs.

Pure bred flocks are now retained almost entirely for the production of rams for crossing purposes, and the cross between Cotswold rams and Suffolk ewes is a very popular one in Norfolk. These first-cross lambs make ideal hoggets for fattening on roots in the winter, from the point of view of both feeder and butcher.

LINCOLN.—These long-woolled white-faced sheep are descended from the old native breed of Lincolnshire, improved by the use of Leicester blood. They are the largest sheep in the world, a weight of 3 cwt. at 20 months being possible of attainment. It has become less and less of a grassland sheep and more and more used by ploughland farmers, and is kept pure in very large numbers, both in commercial and registered flocks in Lincolnshire. (Plate X., 3.)

The carcass is abnormally fat, and the mutton is of poor flavour, the value of the breed as a mutton producer being its early maturity. The glory of the Lincoln, however, lies in the wonderful fleece of lustrous wool. Rams have been known to yield fleeces of more than 30 lb., and ewes will sometimes clip 14 lb. Its power of wool production and its great size have brought it into high repute abroad in sheep countries, where it has a reputation for prepotency.

KENT OR ROMNEY MARSH.—This is an extremely old breed which takes its name from the district and county in which it originated, though, in these days, it is by no means confined to Kent. The breed is much appreciated in its native district and equally so in the continually extending area in the Dominions and abroad, to which it is being exported yearly in increasing numbers. Its hardiness enables it to withstand the extreme climatic changes with indifference, bred as it has been for generations upon the exposed marshes. Nature has during this period gradually but surely left none but those with vigorous and sound constitutions. Few others could thrive successfully in the conditions under which it is generally kept.

It has great adaptability and thrives upon rich and poor pasture.

In lambing time there is no need of costly shelter. They drop their lambs in the open, and the dams take care of their lambs. Probably the most desirable characteristic of the breed from the grazier's point of view, and also that of foreign buyers,

is that the sheep do not flock together and taint the land, but feed and graze singly. (Plate X., 4.)

The wool is demi-lustre, and has become very much more valuable in recent years by reason of the closer attention given to it. The flesh is excellent, when grazed and fed on marshland only. It feeds rapidly, and compared to other longwools produces mutton of high quality, with great depths of lean flesh and small proportion of fat. Another valuable characteristic is its resistance to such diseases as fluke and foot rot. The fecundity, however, is inclined to be rather poor.

WENSLEYDALE.—The Wensleydale longwool sheep is a large high-standing, long-sided, firm-fleshed Yorkshire breed, with a characteristic deep-blue colour in the skin of the face, legs and ears, which sometimes extends over the whole body, though the shade is darker on the bare and hairy parts. The dark colour is favoured because of the extensive use of the rams for crossing with Scotch Blackface ewes, as they throw dark grey-faced lambs. This cross with the Blackface is known as the "Masham." The Wensleydale is rather slow maturing when compared with the Leicester and Border Leicester breeds, and is therefore used for crossing purposes where the production of store lambs rather than fat lambs is aimed at.

The Wensleydale is active and hardy, with a lean carcass of good-quality mutton.

SOUTH DEVON.—This has been for generations a breed covering South Devon and practically the whole of Cornwall. It is a large and symmetrical animal, with a reputation for being able to thrive upon hard fare and in exposed places. The carcass is noted for fulness of meat, and the fleece is of conspicuous merit.

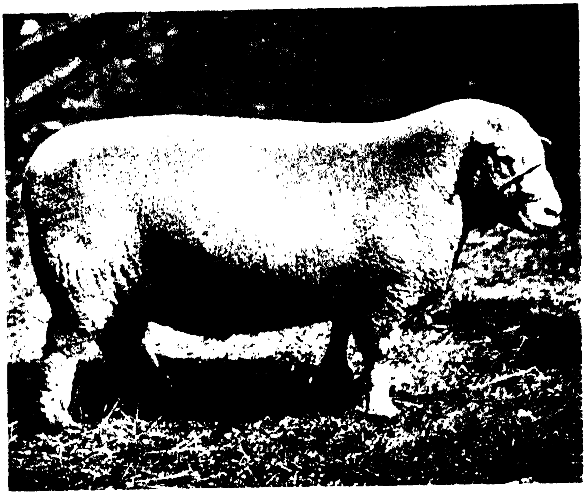
DEVON LONGWOOL.—This is a white-faced breed locally developed in the valleys of West Somerset, North and East Devon, and parts of Cornwall. It originated in a strong infusion of Leicester blood amongst the old Bampton stock in Devonshire. The breed claims to have produced in 1846 the heaviest recorded carcass of a sheep fed in this country—that of a wether weighing 78 lb. per quarter. The long-woolled fleece is of excellent quality.

ROSCOMMON.—This is the only native Irish breed of sheep. They are famous for the quality and flavour of their mutton. They are hardy and active, yet early maturing. The leading characteristics of the breed are size, well sprung ribs, broad level back, strong bone, and fine, long, white, staple wool.

Short-Woolled Breeds.—This group includes all the "Down" breeds, and some which do not readily fall into either of the other two groups.

The various Down breeds were all originally associated with downs or similar districts of fair elevation with dry soil and climate. They are now found under a wide range of conditions in all parts of the country.

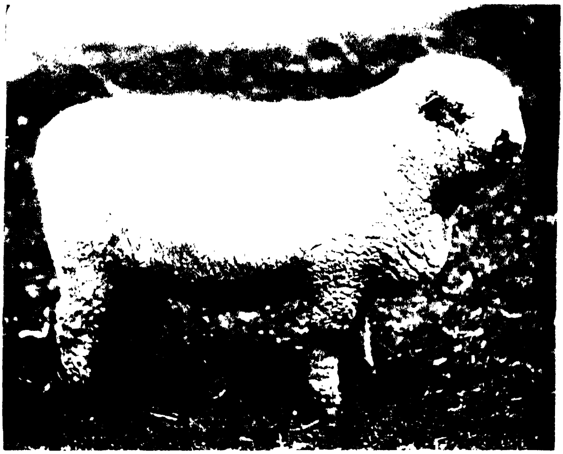
PLATE XI.



1. Southdown Ram

2. Oxford Down Shearling Ram.

PLATE XI.—*continued.*



3. SHROPSHIRE TWO-SHEAR RAM.

4. HAMPSHIRE DOWN RAM LAMBS.

The Down breeds are all primarily mutton-producing sheep, and yield carcasses which are neither too fat nor too large, are firm, fine in grain, and rich in colour. They are hornless, and usually dark in face and leg, with fleeces of close fine wool, comparatively short in length. They are essentially ploughland sheep, though many of them spend some time each year on grass. They are all more or less indebted to the Southdown.

The chief Down breeds are :

Southdown	Shropshire	Hampshire Down
Oxford Down		Suffolk

Into this group too, have been placed the following breeds :

Dorset Horn	Ryeland	Clun.

Southdown.—As the Leicester breed of sheep must always be connected with the name of Robert Bakewell, so must the Southdown be associated with that of John Ellman, of Glynde, near Lewes, who commenced farming in 1780. Working very largely on Bakewell's lines, by selection within the breed, and without the introduction of any alien blood, he evolved from what was an ill-shapen, semi-mountain type of sheep, one which as a mutton producer is second to none. Although Bakewell urged it, the Southdown was never crossed with the Leicester.

The Southdown is a small sheep—the ewes barely average 10 stone live weight—it is so well put together and thick in flesh that its weight is deceptive.

The description of a typical Southdown sheep is as follows. Head wide, level between the ears, with no sign of slug or dark poll. Face full, not too long from eyes to nose, and of one even mouse colour, not approaching black or speckled ; under-jaw light. Eyes large and prominent. Ears of medium size and covered with short wool. Neck wide at base, strong and well set on to shoulders, throat clean. Shoulders well set, and the top level with the back. Chest, wide and deep, back level, with a wide flat loin. Ribs well sprung, well ribbed up, thick through the breast, with fore and hind flanks fully developed. Rump wide, long, and well turned. Tail large, set on almost level with chine. Legs of mutton (including thighs, which should be full) well let down, with deep wide twist. Wool of fine texture, great density, and sufficient length of staple, covering the whole body down to hocks and knees, and right up to cheeks, with full foretop, but not round eyes or across bridge of nose. Skin of delicate bright pink. Legs short, straight, of one even mouse colour, and set on outside the body ; the carriage "corky." (Plate XI., 1.)

The Southdown has been used to improve most of the other Down breeds, and as a mutton producer it excels in its quickness of feeding, early maturity, and prime quality. The frame is small in proportion to the meat it carries, and the sheep is very symmetrical and close to the ground. Not only is it good at all the valuable cuts, but the waste pieces, such as breast and neck, are also good.

The "leg" is ideal, with an enormous development on its inner side. The flesh is of good quality, but can easily be made too fat. The offal as compared with some breeds is small and it has been known to kill 65 per cent. dead to live weight. The ewes are neither very prolific nor particularly good mothers.

As the sheep withstand extremes of heat and cold they are suitable for every climate, and are in great demand for crossing purposes. They have been exported to all parts of the world. Half-bred Southdown lambs have almost ideal conformation, the body being blocky, light in bone, with a perfect leg of mutton. It is widely used for crossing particularly with Kents and Merinos.

OXFORD DOWN.—This is the largest and heaviest of the Down breeds, and is a good example of skilful breeding. In its production the aim was to combine the quality of mutton and fine wool of the Down breed with the weight of carcass and of fleece of the long-woolled types. Certainly Cotswold and Hampshire sheep were used, and probably Southdown as well. The result is a hardy sheep, maturing early and noted for good all-round qualities. As Down mutton the joints are rather big, and inclined to be fat. The sheep thrive well on both arable and pasture land, and in every climate. Unlike some kinds of sheep, Oxford Downs flourish everywhere, and they are exported to nearly every country in the world. They have been much used for crossing purposes particularly in the North with "Half-bred" (Border Leicester × Cheviot) ewes. The progeny resulting from the cross are well adapted for fattening off on turnips in winter under northern conditions. (Plate XI., 2.)

SHROPSHIRE.—This is a medium-sized sheep of great character, very compact and covered with fine short wool. It was derived from the old native sheep of Shropshire and Staffordshire improved by crossing with Southdown rams. In appearance it is not unlike an enlarged Southdown, though heavier in fleece, bulkier in carcass and darker in face, with a helmet of wool. (Plate XI., 3.)

The Shropshire is a good all round sheep, being equally at home on either grass or arable land, though under ploughland conditions the carcass is inclined to become too fat. The ewe is very prolific but rather a poor milker. The fleece is heavy and of good staple, fine in texture, and very dense. It is perhaps the most cosmopolitan of all the Down breeds and is adaptable to various soils and climates. It has the advantage that it can be handled for the butcher at any age.

The rams are used for crossing purposes with Welsh Mountain ewes. The ewes are well adapted to the "lamb and dam" trade.

HAMPSHIRE DOWN.—Early in the 19th century the old Wiltshire horned sheep and the Berkshire Knot roamed over the downs of their native counties. Both these old-fashioned types have long since disappeared, but their descendants are seen in the modern Hampshire, which originated in a cross with the Southdown. The Hampshire is a low set, substantial, strong-boned sheep, darker

PLATE XII.

1. SUFFOLK SHEARLING EWES.

2. DORSET HORN RAM LAMBS.

and with more wool on the face than the Southdown, and very much bigger.

It is remarkable for its early maturity and for its ability to stand heavy feeding and close folding. It can be pushed to attain great weights at an early age, hence it is very popular for the production of early fat lamb. For this purpose it is either kept pure or crossed with other Down breeds, particularly the Suffolk. It is unsuitable as a cross with small ewes, for the Hampshire has a strong heavy head, and if crossed with small ewes, trouble at lambing often results. The mutton is of good quality and fairly lean. Unfortunately the fecundity is rather low, possibly as a result of long continued breeding from single rams in the effort to attain early maturity. (Plate XI., 4.)

SUFFOLK.—These short-woolled, black-faced hornless sheep which originated in the crossing of the old Norfolk horned ewes with Southdown rams, have been recognized as a pure breed since 1810. Perhaps no breed has made such rapid strides in the last 40 years, and its popularity increases year by year. This is due to a combination of three valuable characters which it possesses in a high degree. It is very prolific, a tremendous milker, and remarkable for the high proportion of lean meat in its carcass. The record of the breed in various competitions open to all breeds at the Smithfield Club Show is unequalled. (Plate XII., 1.)

Suffolks possess very hardy constitutions and though they pay for generous treatment will do well on moderate fare. They have a power of recovering condition only equalled by mountain sheep. Suffolk rams are in great demand for crossing purposes. Crossed with the longwool breeds they produce a fine carcass of lean meat. Large numbers of Suffolk rams are used for crossing with half-bred ewes (Border Leicester × Cheviot) and for this purpose the Suffolk has replaced the Oxford Down in many districts.

DORSET HORN.—This breed has been naturalized in the county of Dorset from time immemorial. Both ewes and rams are horned. They are hardy and will do well on most land, but respond well to better treatment, and will thrive either on grass or between hurdles.

As a breed they are remarkable in that they will take the ram practically the whole year round. This makes it possible to produce two crops of lambs from them within 12 months, though the practice is not recommended. At the same time it is not uncommon to put them to the ram so that they lamb in the early autumn and produce prime fat lambs for the Christmas market. Before imported lamb became so good and cheap the public were willing to pay very high prices for this luxury article. (Plate XII., 2.)

The ewes are prolific, excellent nurses, and can be fattened off while suckling their lambs.

RYELAND.—The Ryeland of the present day retains to a great extent the hardy constitution of its progenitors, which Youatt (1837) speaks of as one of the hardiest and most valuable of our British breeds. It has now, however, greatly increased in size and improved

in symmetry. In appearance not unlike a large Southdown it has dull white face and legs and a fleece of wool which excels even the Southdown in fineness of fibre and in the number of its serrations to the inch. The mutton is of fine quality, and the rams are rapidly gaining favour for crossing purposes as sires of fat lambs. The sheep are generally noted for thriving on cold damp soil.

CLUN.—A local breed in West Shropshire and the adjacent parts of Wales. It is descended from the small speckle-faced sheep that once occupied the district, but has been much modified by crossing with rams of the now extinct black-faced Long Mynd breed, and latterly with the Shropshire. It can be regarded almost as a hardy variety of Shropshire, specially adapted to its own locality.

CHAPTER XXIII.

PIGS: ECONOMICS, FEEDING AND GENERAL MANAGEMENT, BREEDS

PIGS are kept to supply four main categories of produce, namely fresh meats such as pork and sausages, cured meats such as bacon and hams, lard and bristles. So far as Great Britain is concerned only the production of pork and of bacon are important, the bulk of our lard supplies coming from the United States. The keeping of pigs for supplying bristles is largely confined to Russia and China. The pigs kept in this country, however, are only sufficient to supply approximately half of the bacon and pork consumed, and the value of the imports of pig meat is between £50,000,000 and £60,000,000 per annum. In order to be profitable pig production like any other financial undertaking must show a satisfactory margin between cost of production and selling price, and in the attainment of this margin the following points are important. Firstly the carcass produced must be of the conformation and texture required by the trade. Even if, as at present, no premium is paid directly to the producer for the better quality pigs yet their production is indirectly of benefit by increasing the demand for British products. On the other hand the cost of production must be brought as low as possible, and this is effected both by rearing as large a number as possible of piglings per sow per year, thus reducing breeding charges, and by obtaining a unit of carcass increase in weight for the consumption of the smallest amount of food in order to keep to a minimum the charges for food which form such a very high proportion of the total costs. The general standards required to fulfil this condition may be roughly taken to be as follows.

CARCASS.—The pig-keeper has to produce a carcass which best meets the requirements of the butcher and bacon curer. From Figs. 86 and 87 it will be seen that the ideal conformation from this

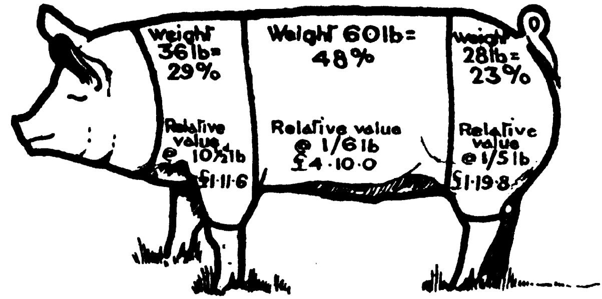


FIG. 1. WEIGHT AND RELATIVE VALUE OF FORE END, MIDDLE AND CAMMON RESPECTIVELY OF A BACON PIG.

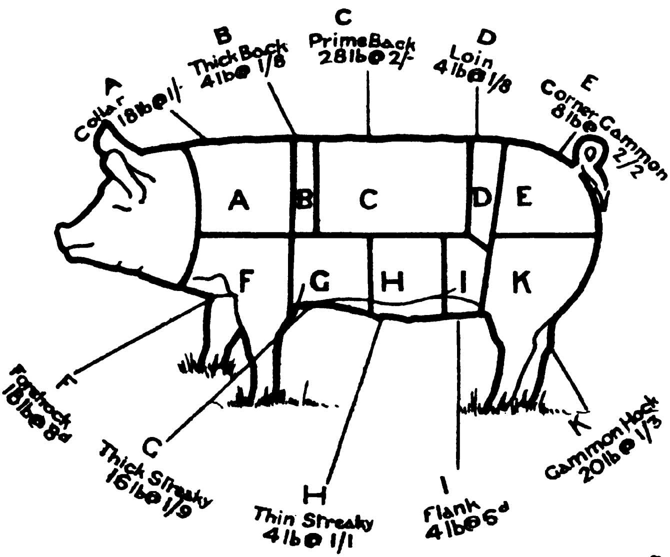


FIG. 2. STANDARD RETAIL CUTS OF WILTSHIRE BACON IN RELATION TO THE LIVE PIG.

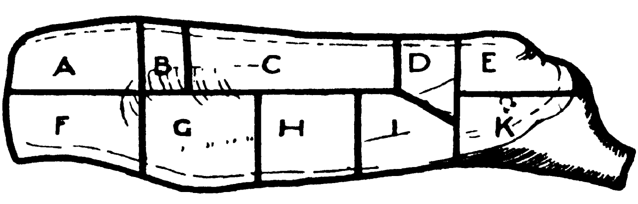


FIG. 3. STANDARD RETAIL CUTS OF A WILTSHIRE SIDE.

FIG. 86.—From "Report on the Pork and Bacon Trades in England and Wales."

point of view is one in which there is a long and broad middle and heavy and well-shaped hindquarters; the fore-end, head and legs should be as light as possible without interfering with the chest and heart room necessary for constitution.

FECUNDITY.—If a sow weans eight pigs twice per year they will cost approximately 25/- each at weaning whereas if only six are weaned per litter the cost will rise to something over 36/-. For an eight weeks old pig this is too high a figure to leave a reasonable margin for profit, and not less than fourteen weaned pigs per year should be aimed at as a minimum. Any number over eighteen per year will be very good. At eight weeks old the average live weights should be from 25 lb. to 32 lb.

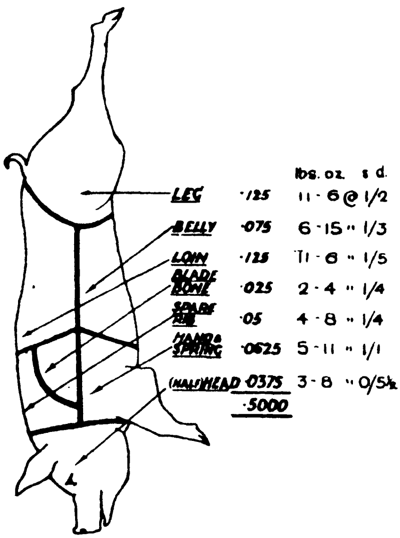


FIG. 87.

Adapted from "Report on the Pork and Bacon Trades in England and Wales," Ministry of Agriculture Economic Series. No. 17. By permission of Controller of H.M. Stationery Office.

ECONOMY OF FOOD CONSUMPTION.—Under practical conditions it is very difficult to obtain an accurate record of the food consumed per pound of live weight gain. It has been proved, however, that the more rapidly the pig fattens the more economical it is in converting its food into live weight gain. The age at which any given weight is achieved is therefore a reliable and at the same time easily obtained indication of efficiency of food conversion. As a guide to the standard age for weight figures which should be aimed at the following table may be taken. For any given weight a pig

above the maximum age will only yield a profit under exceptional conditions.

Class.	Max. live weight.	Age in days at max. live weight.
Sucklers.—		
Birth to 30 lb.	30 lb.	52— 63
Stores.—		
30 lb.—90 lb.	90 lb.	122—150
Porkers.—		
90 lb.—100 lb.	100 lb.	130—160
Porkers.—		
100 lb.—125 lb.	125 lb.	149—183
Cutters.—		
125 lb.—180 lb.	180 lb.	186—228
Sizeable Baconers.—		
180 lb.—240 lb.	240 lb.	215—264
Stout Baconers.—		
240 lb.—270 lb.	270 lb.	227—280

To be successful in pig-keeping it is essential to watch that the standard requirements in these three categories are being fulfilled, and this involves the keeping of records either privately or through an official pig recording organization. Financial success is more a matter of careful management than of any particular food, breed or equipment, and attention to the following points will help in the attainment of the desired results.

Feeding and General Management.

(*a*) Breeding Sows.—Sows should be served at the first heat period after weaning and this normally occurs within ten days. It is not good practice to allow the sow to run with the boar at this time. She should be allowed one service only at approximately 48 hours after the onset of heat and if possible should be kept away from other sows for another day. Thereafter she should be run out on pasture till within about a week of farrowing. When sows require to be ringed this should be done either before service or very shortly afterwards. Heat occurs approximately every 21 days and it is therefore necessary to examine sows from about the 19th to 23rd days after service to see whether they are "turning" to the boar, that is coming on heat again.

While sows are running on pasture during the in-pig period they will require from 3 to 6 lb. of concentrates according to the feeding value of the grazing. On an average 4 lb. is likely to be about the amount required, but this must depend on the condition of the animals which is usually low after weaning and which has to be improved without causing fatness.

About one week before farrowing, sows should be brought into the pen in which they are to farrow in order to get accustomed to it. It should previously have been thoroughly cleaned out and disinfected, and the provision of farrowing rails is an advantage. Plenty of fresh, clean straw, preferably wheat, should be supplied and

if the sow is in the pen for a week it will be found that the straw will be chewed up by her into small lengths which will prevent any trouble with the newly-born pigs. During this last week the sow's food should consist of 3 lb. of scalded bran and 3 lb. of concentrates per day, in two feeds, and if there is any indication of constipation, nothing but scalded bran should be fed as it is absolutely essential that the bowels should be normal at farrowing.

It is on the whole advisable that the attendant should be present during farrowing but no assistance should be given unless it is really required. If the sow has been allowed to make her bed properly it will not be necessary to nip off the navel strings. Teeth should only be broken off with pincers if the young pigs are definitely irritating the sow. The latter should not receive much solid food for 12 or 24 hours after farrowing as there is a risk of over-stimulating the milk supply and producing inflammation of the udder, a condition which is often responsible for very great losses. On the other hand a thin gruel containing a little meal or preferably bran will keep the sow from being restless and crushing the piglings. During the first three days the condition of the udder must be very carefully watched and inflammation prevented by keeping the bowels open and the animal on a very light diet. When this period is safely over the ration may be slowly raised to what the sow will consume without putting on flesh. This will usually be about 10 lb. but may be more in the case of a deep milking sow.

At about 3 weeks old the young pigs will begin to feed and should be encouraged to feed from their own trough. Where the labour available is not very skilled dry feeding is safer for young pigs, but otherwise better results can probably be obtained by feeding wet especially where milk is available or the feed can be warmed. To begin with sharps are one of the safest feeds, but small quantities of barley meal or flaked maize are also valuable. Fish meal or meat meal should only be used sparingly at first, but milk or its bye-products are always useful and safe. At 6 weeks old the male piglings not required for boars should be castrated and all pigs requiring to be tattooed or earmarked are best done at this time. To get successful results at weaning the piglings should be taking the maximum amount of solid food and the minimum of milk from the sow. For this reason the piglings should be kept away from the sow for increasingly longer periods during the last ten days or so and the sow's rations should be gradually cut down during this period till, at 8 weeks after farrowing, she is getting not more than 6 lb.

Weaning will be less of a shock to the young pigs if they are kept in their farrowing pen and the sow removed than if they are immediately removed to strange quarters.

(*b*) Fattening Pigs.—Pigs which are being fattened to be sold at light pork weights, say not more than 120 lb. live weight, will require a rather more fattening ration than those kept on to bacon weights, but for the first month after weaning both will benefit

from running out on pasture provided always that they have a warm house to sleep in or to lie in at will. During this period they should be given all they will eat in addition to grazing. At 12 weeks old in the case of pork and perhaps a week or two later for bacon they should be brought into fattening pens or yards where they will be confined under cover till ready for slaughter Sufficient trough room should always be available and the pigs should be warm and dry throughout the fattening period. As a rule three feeds per day will be given up to a live weight of about 100 lb. and thereafter two. Fresh drinking water should always be available whether wet or dry feeding be adopted. To obtain the best results it is essential that the meals should be given regularly, that is to say, always at the same time and that the amount given is just sufficient to satisfy the pigs without any food being left in the trough. Overfeeding is one of the first things to produce a set-back to fattening pigs.

It is usual to divide suitable pig foods roughly into two groups, those of a nitrogenous nature which supply protein, and starchy feeding stuffs which supply energy. The latter form the basal part of the ration and in this group are included such cereals as barley, wheat, rye, oats, maize and millet; milling offals such as bran, sharps, rice meal and oat feed; roots and tubers such as potatoes (always boiled) artichokes, mangolds, turnips and sugar beets, and miscellaneous foods such as locust beans, treacle and whey, all of which have a nutritive ratio wider than 1 : 5. The nitrogenous foods are usually considered to be supplementary to the others and may be roughly defined as those having a nutritive ratio narrower than 1 : 5. They include animal products such as meat meal, whale meal, fish meal, blood meal, dried yeast and milk bye-products except whey; dried vegetable products such as beans, peas, palm kernel cake, coco-nut cake, linseed cake, earthnut cake, extracted soyabean cake, the meals made from these oil cakes, and maize gluten feed; and fresh vegetable products such as young pasture grass, rape, lucerne, clover, tares and sainfoin.

The particular foods, or amounts of them which are used in each group will, of course, depend on price and availability. It is necessary, however, to adjust the relative proportions to the needs of pigs at different weights and the simplest way to do this is to take the nutritive ratio of the whole ration as a guide.

In addition a relatively high proportion of lime is required in the diet both of breeding and of feeding pigs and this is best supplied in the form of ground limestone or of ground chalk. Lime, however, is not utilized to the best advantage except when the pigs are exposed to direct sunlight. When this is absent the Vitamin D contained in cod liver oil should be added to the ration. The three following rations will indicate the approximate types and amounts of feedings most suitable at different weights, but these, of course, must be varied according to circumstances.

I. STORES.—30 lb. to 90 lb.

Sharps	15 parts	Approx. Nutr. Ratio 1 · 4.
Barley Meal ...	5 ,,	
Flaked Maize ...	5 ,,	
Fish Meal ...	1 ,,	
Ground Linseed	1 ,,	
Sep. Milk ...	54 ,,	

II. SMALL PORK PIGS.—90 lb. to 125 lb.

Sharps	30 parts	Approx. Nutr. Ratio 1 : 5.
Barley Meal	45 ,,	
Maize Meal	15 ,,	
Fish Meal	4 ,,	
Meat Meal	4 ,,	
Ground Limestone	2 ,,	

III. BACON AND LARGE PORK PIGS.—125 lb. to 240 lb.

Sharps	25 parts	
Barley Meal	40 ,,	
Maize Meal	30 ,,	
Meat Meal	4 ,,	
Ground Limestone	2 ,,	Approx. Nutr.
or		Ratio 1 : 6½.
Sharps	40 ,,	
Boiled Potatoes...	300 ,,	
Sep. Milk	100 ,,	
Ground Limestone	1 ,,	

Green food, if it is of good quality, may be fed in the sties to fattening pigs up to an average amount of 6 lb. per head per day if it is available and as cheap as concentrates. For purposes of comparison 1 lb. of meals or 6 lb. of milk are equivalent to 9 or 10 lb. of green food. Even where green food is not fed as a definite part of the ration small quantities should be given every day along with a certain amount of soil, ashes or coal dust.

(*c*) YOUNG BREEDING STOCK.

In the case of young gilts and boars which are being kept for breeding the aim must be to develop constitution while keeping the costs of production as low as possible. This is best achieved by running the pigs out on pasture all the time and giving them smaller quantities of food than is given to fattening pigs of the same weight. They may be housed in movable huts provided they are warm enough, but care should be taken in winter time that sufficient fresh grazing is available to prevent the ground round the entrance of the hut from becoming too poached. Young boars will require to be segregated from the gilts at about 4 months and should not be used for service before they are 8 months old. Even then they should be sparingly used, particularly at first, until they are at least a year old. Young gilts should be brought into a rising condition when 7 months of age so that when served at about 8 months they are in rather more than store condition. Both during the time they are in pig and while suckling their first litter they should be kept in definitely higher condition than is usual in the case of a sow.

(*d*) Minor Ailments and Diseases.

Of the diseases which attack pigs the most serious are Swine Fever, Swine Erysipelas and Tuberculosis. The first two are caused by infection either from pig-sick land or from animals bought through a market. When the disease has been contracted veterinary advice should be sought. Tuberculosis in pigs is nearly always due to the consumption of milk infected with bovine tuberculosis, and the pasteurization of the milk is the best way to eradicate it. Sows which are known to be tubercular should be got rid of as they infect their litters very easily.

Much more loss than is usually believed is, however, caused by minor ailments due to parasites. Mange, lice and nematode worms are responsible for a very serious loss of condition and consequently of profit. They can be almost entirely eliminated yet this is very seldom done. Mange is treated by scrubbing the pigs with a non-carbolic wash and by disinfecting all wooden posts or corners on which the animals can rub. Lice are killed rapidly by the application of any kind of oil to the infected parts, normally behind the ears and along the back. Nematode worms can be removed by dosing with santonin or with a mixture of 5 parts of oil of chenopodium in 95 parts of castor oil. The proper dosage will be found in any veterinary book, but in both cases it is essential to fast the animals well before dosing.

Breeds

Over a dozen separate breeds have at different times been recognized in Great Britain. There are various reasons why these should have been developed, but very few why they should all be perpetuated. Whether or not two types of carcass are required for the bacon and pork markets is a much discussed question, but there is both practical and scientific opinion to support the view that a type which produces really good bacon will not be unsuitable for the production of pork. For all general purposes the Large White or Large Yorkshire as it is known abroad, is the most suitable. To produce the first cross, which is regarded with such favour by so many breeders and curers, the Large White boar may be crossed with sows of the Large Black, Berkshire or Middle White breeds. It has to be remembered, however, that generally speaking there is a greater difference between different strains within the same breed than between the average of the breeds themselves For this reason less attention need be paid to the so-called standards of excellence of the different breeds, than to the records of production achieved by individuals or by strains within the breed. The examination of carcasses at a bacon factory or slaughter-house coupled with a study of such weaning and age for weight records as are available for the different breeds will lead to a better understanding of the breed characteristics than is obtainable in the showyard.

The most important of the recognized breeds in this country are:—

Large White	Tamworth
Middle White	Large Black
Small White	Small Black (Suffolk or Essex)
Berkshire	Lincoln curly-coated

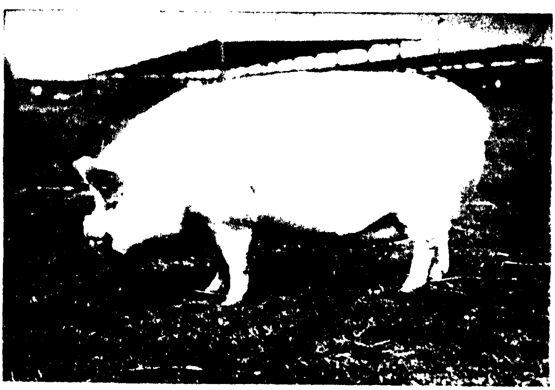
LARGE WHITE (Plate XIII., 1).—No variety of pigs has made a greater advance in public favour during the last quarter of a century than the Large White breed. Probably one of the chief reasons for this increased demand has been the extreme suitability of these pigs and crosses between Large White boars and sows of all other varieties for the purpose of the curer of bacon, an article which has become one of the most general breakfast dishes. The white colour which it also impresses so invariably on its produce from sows of any other colour is a valuable asset, as is proved by some bacon curers actually paying a premium on white pigs, since bacon from animals of that colour sells more readily and at a higher price on some of the markets than bacon manufactured from pigs of a dark colour. This, of course, is fancy on the part of the consumer to a certain extent, but it is also an admitted fact that the Large White pigs furnish a larger proportion of lean to fat meat than almost any other breed, so that the consumer who may not be a keen judge of the merits of bacon in an uncooked state has one easy and sure test of the probable leanness of the meat by noticing the colour of its skin. Amongst other advantages possessed by pigs of the Large White breed are their quick growth, their early maturity, and their readiness for slaughter at an early age where small pork is in fashion, or for the production of those very fat and heavy pigs of 300 to 500 lb. dead weight, which are in demand in some parts of the so-called Black Country. The sows, like the boars, are of quiet disposition and very prolific; the sows produce a full flow of milk, which is continued until the piglings are old enough to be weaned. These last are hardy and quick growers, being greatly in demand in those dairying districts where cheese and butter are manufactured for the production of the greatly esteemed dairy-fed pork.

The Large White pig will grow into a large size when fully matured, boars of 10 cwt. and sows of as much as 9 cwt. live weight having been known. They should be long in the head, with ears slightly inclined forward, jowls light but the forehead wide, the neck fairly muscular, the shoulders obliquely placed (so that an appearance of narrowness is given to the shoulder), the ribs well sprung, the back long, the body deep, with a well-developed flank, the loin muscular, the hind quarters long and wide, and the hams extending quite to the hocks. The legs should be set well outside the body, the ankles firm, the bone fine and hard, the skin firm and thin, the hair plentiful, straight, and of a fine texture.

MIDDLE WHITE (Plate XIII., 2).—The description given above of Large White pigs will apply in most of the particulars to Middle

PLATE XIII.

1. Large White Sow.



2. Middle White Sow.

PLATE XIII.—*continued.*

3. Berkshire Boar.

4. Tamworth Sow.

White pigs, save as to extreme size, length of body, and the shape of the head, which is much shorter, with heavier jowls, and smaller and more erect ears. The Middle White pig is also finer in the bone, skin, and hair, and altogether neater in appearance. Although the Middle White Boar is preferred for crossing on to the large and coarse sows in some districts for the production of pigs suitable for the manufacture of bacon, and a number of boars of this breed have been exported to Russia, Australia, and some other foreign countries for the same purpose, yet the Middle White is more suitable for the fresh pork trade, whether in the form of London porkers, weighing alive about 100 lb., or in the country where pigs of the weight of 120 to 150 lb. are most in demand. A very large number of pigs suitable for the fresh pork trade are also begotten by Middle White boars from sows of other breeds, particularly those of the Large White and Berkshire breeds. Pigs of the latter cross have been shown of late years at the Smithfield Club shows which nearly approach to perfection in form and quality of fat pigs. Not only so, but these cross Middle Whites and Berkshires mature early, and furnish carcasses of fine pork by the consumption of a comparatively small quantity of meal. The cross between Large White and Middle White is probably the best type of pig for farmers' purposes, especially in those districts where heavy fat pigs are more in demand than those of a medium size.

Small White.—These were in great favour some forty years ago, when pork with a much larger proportion of fat to lean meat was in more general demand than at the present time. These pigs were white in colour. They possessed a heavy covering of hair, were very compact in form, fine in bone, and came early to maturity.

Berkshire (Plate XIII., 3).—These animals are claimed to have been introduced and developed into a distinct breed in West Berkshire, and during the past fifty years most careful attention has been given to their improvement, with the object of producing the best type of animal for the butcher.

The colour of the Berkshire is black, with feet white to about the ankle joint, white tip to tail, and white on the face.

The general conformation should be long, low, level, and deep, straight back, tail set high, head moderate length and dished, wide between the ears, ears fairly erect (not drooping over the face), fringed with hair; ribs well sprung; good length from hip-bone to tail; legs strong, straight, and set square; hair plentiful and fine over all the pig.

They are regular breeders, hardy and most suitable for export, being especially adapted for all climates; not affected by sunburn. Quiet disposition, good mothers, easy feeders, and good foragers; active and mature very early.

They are now a leading type in all the principal showyards, where distinct classes are given for them, in which the best specimens of the breed may generally be seen to advantage. From a judge's

point of view, the first considerations for merit are the desired colour, with fine hair and skin, a shapely head and nicely set ears, and large hams, combined with length and depth of body and quality.

TAMWORTH (Plate XIII., 4).—This breed is most abundant in the Birmingham district, and is more closely related to the wild boar than the other kinds of native pig, as indicated by its hardiness, active habits, long snout, and comparative leanness of the meat it produces. The old type, however, has been modified by the introduction of the Yorkshire blood.

Tamworths should conform to the following standard of excellence : Hair golden-red (free from black), on a flesh-coloured skin, abundant, long, straight and fine ; head fairly long, snout moderately long and quite straight, face slightly dished, wide between the ears ; ears rather large, with fine fringe, carried rigid and inclined slightly forward ; neck fairly long and muscular, especially in boar ; chest wide and deep ; shoulders fine, slanting, and well set ; legs strong and shapely, with plenty of bone and well outside body ; pasterns strong and sloping ; feet strong, and of fair size ; back long and straight, loin strong and broad ; tail set on high and well tasselled ; sides long and deep ; ribs well sprung and extending well up to flank ; belly deep, with straight underline ; flank full and well let down ; quarters long, wide, and straight from hip to tail ; hams broad and full, well let down to hocks ; action firm and free.

Tamworth crosses are noted for their hardiness.

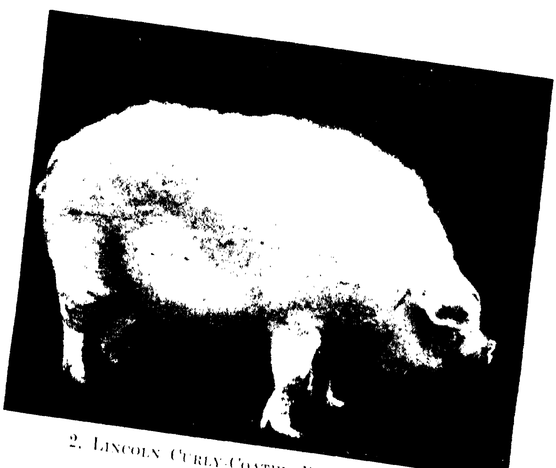
LARGE BLACK (Plate XIV., 1).—This is one of the oldest breeds, and there are two original types, one from Devon and Cornwall, the other from Suffolk and Essex. The former are larger and more refined, the latter hardier and more prolific. The good qualities of both strains will no doubt ultimately be fully blended. The Large Blacks can claim to be a utility breed, suited to the needs of the modern breeder, feeder, bacon-curer, and consumer. They were formerly fed to enormous weights, but weight has now given way to greater quality, and the breed yields at a very early age the chief desideratum—viz., a long, deep-sided carcass of 160 to 190 lb. dead weight, light in shoulder, jowl, and offal, and showing a larger proportion of lean meat than any other breed.

Large Blacks are very docile, and the forward carriage of the ears is supposed to conduce to quiet field grazing. The colour is claimed to enable summer pasturing or field feeding without risk of sun-scald. The sows are noted for their fecundity.

Large Blacks should conform to the following standard : Head of medium length, and wide between the ears ; ears thin, inclined well over the face, and not extending beyond point of nose ; jowl of medium size ; neck fairly long and muscular ; chest wide and deep ; shoulders well developed, in line with the ribs ; back long and level, and ribs well sprung ; loin broad, and sides very deep ; quarters long, wide, and not drooping ; hams large, and well filled to hocks ;

PLATE XIV.

1. Large Black Boar.



2. Lincoln Curly-Coated Breeding Sow.

tail set high and of moderate size; legs short, straight, flat, and strong; skin fine and soft, with a moderate quantity of straight, silky hair.

SMALL BLACK.—This name is given to local races characteristic of Suffolk and Essex, and much resembling the Small White, except in colour, the possession of scantier hair, and greater length of body and leg. Small Blacks have a small, well-formed head and symmetrical figure. They fatten well, yielding a good proportion of lean meat, and mature early.

LINCOLN CURLY-COATED (Plate XIV., 2).—Until the last few years this ancient breed of large pigs was only well known in East Lincolnshire. The abundant white hair is curly, as the name indicates, and the skin is of the same colour, though some blue spots are usually present. The face is shorter than that of the Large White, and the ears (which should be of moderate length) fall over it, while the nose is straight. It is claimed to be unequalled for early maturity and development, and is undoubtedly hardy and vigorous. It crosses well with other breeds, particularly Berkshire, Large White, and Large Black.

CHAPTER XXIV.

POULTRY AND POULTRY KEEPING.

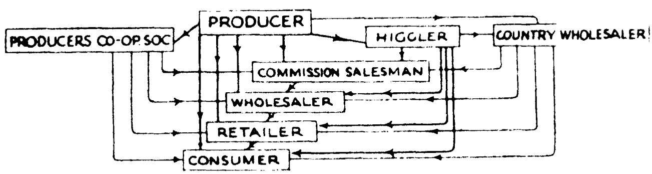
THE advantage of poultry keeping as a commercial asset to the general farm has only recently been recognized. The general farmer possesses natural advantages over the commercial poultry keeper in that a large proportion of the food required by poultry is produced on the farm itself, and accommodation for rearing and laying birds is already available free of cost, in the sense that fields can be utilized for these purposes without interfering in any way with the use to which such fields are usually put in the normal course of husbandry operations. Indeed, so far as pasture land or meadow land is concerned, provided that the birds are limited to 50 per acre, the value of the land for other livestock is enhanced rather than depreciated. In deciding to include poultry keeping as a branch of his normal husbandry, the farmer must, however, regard it just as seriously, and with as much attention to detail, as he does to the other branches of livestock husbandry, if he wishes to make a success of it. The impression that poultry will flourish under any circumstances and conditions on the average farm is now rapidly being recognized as erroneous.

So far as farmers are concerned, there are two main types of poultry farming, namely, commercial egg production and table meat production. Arising out of these two main branches of poultry keeping, and, in a sense, parasitic upon it, are the specialist forms of poultry keeping, such as pedigree breeding, sales of hatching eggs,

three-month-old pullets, day-old chicks and breeding stock. A more recent development is the setting up in various parts of the country of commercial hatcheries, the object of such hatcheries being the supply of day-old chicks to farmers and others who prefer to buy day-old chicks rather than hatch the eggs out themselves. The introduction of these hatcheries has benefited farmers who keep breeding flocks, since, during the breeding season, when eggs are relatively cheap, remunerative contracts may be made with such hatcheries for the supply of hatching eggs.

Although poultry keeping on the farm may gradually develop into one of the specialist forms of poultry keeping mentioned above, the main business of the farmer should consist of commercial egg production, with table poultry production as a side line.

Marketing—The marketing organization of eggs and poultry is a very complex one, and the channels through which these products pass from the producer to the consumer are many. There are no less than seven different classes of persons to whom the farmer may market his poultry produce, and the various channels through which the produce passes on its way to the ultimate consumer is indicated in the diagram below, which has been adapted from the Bulletin No. 11, published by the Ministry of Agriculture and Fisheries.



Each of these classes of persons concerned in the egg and poultry meat trade plays an important part in maintaining a steady flow of poultry produce from the producer to the consumer, and together they form the links of the elastic machine whereby supplies are diverted to any portion of the country where a temporary demand for the product in question exists. The higgler collects direct from the farms, provides his own packing materials, and pays cash. The country wholesaler collects, re-packs and re-sells. The Producers' Co-operative Societies fulfil the same functions as the country wholesaler, but in this case the profits made for the services rendered (or the losses incurred) are returned to the producers. The commission salesman and the town wholesaler fulfil very much the same function, but the commission salesman acts as a sales agent only, receiving a commission for his services, whereas the town wholesaler buys outright, depending for his remuneration on the margin between the price at which he buys and the price at which he sells.

Apart from sales to individuals, a considerable trade is done in country districts by sales at country markets and auctions.

Marketing Conditions. Eggs.—The price realized for eggs varies according to supply, demand and quality. The price received for home supplies is affected by foreign and colonial imports, which have a steadying influence on rise of prices for home supplies. In actual fact, the foreign and colonial exporter only becomes an active competitor with home supplies when the price of eggs rises to a point at which it pays him to export his produce. In addition to this, as the price of eggs rises the actual demand for eggs for home consumption drops owing to the limited purchasing power of potential consumers of poultry products. Attempts to raise the price of eggs beyond the stage which provides a fair margin of profit for the producer are apt, therefore, to defeat their own object, since not only do such efforts encourage foreign and colonial competition but they also result in a severe contraction in market demand. Apart from market demand, the season materially affects supply. During October to February, inclusive, when approximately only 31 per cent. of the total yearly home production of eggs are produced, prices are generally good, whereas during the remaining seven months of the year the prices are generally low. Since the increased supply of eggs available during these months is largely due to farm supplies, it is obvious that farmers should pay increasing attention to the necessity of encouraging winter egg production if better prices for their eggs are desired.

The question of quality is an extremely important one, since the consumer always requires a sound, reliable article at a reasonable price, and unless these requirements are satisfied a repeat order will rarely be forthcoming. Organized marketing of a standardized product, packeted in an easily recognisable form, is therefore extremely important in creating a steady sales demand, and for this reason the efforts made by the Markets Section of the Ministry of Agriculture in the direction of National Mark Products, should receive the unqualified support of the farmers in their own interests. The external characteristics of quality are good colour of shell (brown being favoured), firm shell, good bloom, free from blemish. The internal characteristics of quality are good flavour, small air space, firm white, good yolk colour, and free from blemish. The definition of quality in the National Mark Scheme is "The egg must not have been preserved, the shell must be clean and sound, the yolk translucent or faintly but not clearly visible, the white translucent and firm, and the air space must not exceed ¼ in. in depth." It is obvious, of course, that candling is essential to recognize some at least of the characteristics expected in an egg of good quality. Under the National Mark Scheme, the first-quality eggs are graded according to weight into the following classes: Specials 2¼ oz., Standards 2 oz., Mediums 1¾ oz., Pullet 1½ oz.

Poultry Meat.—Several classes of trade are recognized, and owing to the perishability of the product and the seasonal nature of the demand, meat production is a more specialized business than egg production. The table which follows gives the main points of

economic interest with regard to meat production. With regard to dressing, type of pack, etc., the demands of the market should be closely followed.

Class of Product.	Weight per dozen in lbs.	Time Marketed.
Petit poussin	6–12	Up to Mar.–April.
Asparagus chicken	12–24	Early summer.
Spring chicken	24–42	April–July.
Country chicken	42–72	Jan.–June.
Capons	84	Christmas.
Roasters ... ... (Young hens, laying pullets and young cockerels.)	48–96	Best period for marketing Jan.–May and December.
Boilers ... ... (Hens and cocks surplus to requirements.)	60	

FOWLS

The Origin of the Domestic Fowl.—Fowls were brought under domestication by man in comparatively early times, and their distribution through the world has followed the spread of early civilization. There is little doubt that the sport of cock-fighting was a predominating factor in their early distribution and domestication, their development for meat and egg production occurring in the later stages of civilization. Darwin assigns the wild jungle fowl, *Gallus bankiva*, as the progenitor of all our modern breeds, but the fact that certain of the genetic characters of our domestic breeds are dominant to *Gallus bankiva* strongly supports the view that our domesticated breeds have a multiple origin, and that other strains of Gallus have also contributed to the production of our modern races of fowls.

Classification of Breeds.—From the poultry farmer's point of view, the various breeds of fowls are classified according to their economic qualities, as layers, table birds and general utility or dual-purpose breeds. The poultry Fancy also distinguish between exhibition types of fowls and utility types. In addition, most of the common races of fowls have been bred to the same standard except with regard to size of body, the especially small types thus bred being classified as " Bantam."

Thus the Old English Game cockerel weighs from 5 to 6 lb., the Old English Game bantam weighs from 18 to 22 oz.

The common breeds of poultry in use in Great Britain comprise the following :—Anconas, Andalusians, Australorps, Barnevel ers, Brahmas, Bresse, Campines, Cochins, Croad Langshans, Dorkings, Faverolles, Old English Game, Hamburghs, Houdans, Indian Game, Langshans, Leghorns, Minorcas, Orpingtons, Plymouth Rocks, Rhode Island Reds, Scots Greys, Sussex and Wyandottes.

TABLE I.

Body Colour.	Leg Colour.	Type of flesh.	Comb.	Egg colour.	Weight. lbs.	Remarks.
Egg laying Breeds.						
Ancona	Yellow, mottled with black	Yellow	Single	White	5—7	Good layers, non-sitters, free range.
Andalusian ...	Dark slate	Grey to grey-white	,,	,,	4½—7	Good layers, non-sitters, free range or confinement.
Campine ...	Slate blue	greyish-white	,,	,,	3½—5½	Good layers, non-sitters, free range, light soil, hardy.
Coveney White	Yellow	Yellow	Cup	,,	3½—5½	Good layers.
Hamburghs ...	Dark or slate blue	Grey	Rose	,,	3½—5½	Good layers, non-sitters, small egg, free range.
Houdan... ...	Pinky-white mottled-black	Creamy-white	Leaf	,,	—	Good layers, non-sitters, confinement.
Leghorn ...	Yellow	Yellow	Single	,,	3½—6	Good layers, non-sitters, free range and confinement.
Minorca White ...	White	White	,,	,,	5—7	Good layers, non-sitters, large egg, non-hardy.
,, Black ...	Dark slate	Grey	,,	,,	5—7	Good layers, non-sitters, large egg.
Table.						
Bresse	Blue-grey	White	,,	,,	4½—6	Excellent flesh, moderate sitters, fine bone.
Dorking ...	White	White	,,	,,	7—12	Excellent flesh, early layer, free range, coarse bone, light soil.
O. E. Game ...	Variable	Variable	,,	Tinted	5—9	Excellent flesh, pugnacious, free range. Table, heavy bone, slow growth.
Indian Game ...	Yellow or Orange	Yellow	Pea.	Dark brown	6—10	Free range, excellent for crossing with other breeds.
Sussex	White	White	Single	Tinted	7—9	Excellent flesh, light bone, good egg layers, hardy.
Dual purpose.						
Barnevelder ...	Yellow	Yellow	,,	Dark brown	5—8	Well flavoured meat, good winter layers, hardy.
Brahma... ...	,,	,,	Triple or Pea.	Medium brown	7—11	Hardy, good winter layers, small eggs.
Cochin	,,	,,	Single	Dark brown	7—13	Moderate layers, small eggs, heavy feeders.
Faverolles ...	White	White	,,	Dark cream	5—9	Hardy, good winter layers, good sitters.
Langshan ...	Dark grey	Grey	,,	Dark brown	6—10	Not very hardy, small eggs, good sitters.
Orpington ...	White	White	,,	Medium brown	6½—10	Hardy, good layers, good table bird, stands confinement well.
,, Black ...	Black	Grey or greyish-white	,,	,, ,,	6½—10	
Plymouth Rock	Yellow	Yellow	,,	Brown	8—9	Good size winter eggs. Inclined to be broody, Large carcass.
R. I. Red ...	,,	,,	,,	Dark brown	5½—8½	Very hardy, good layer, well fleshed, good foragers.
R. I. White ...	,,	,,	Rose	Brown	5½—8½	,, ,, ,, ,,
Scots Grey ...	White	Mottled	Single	White	5½—8	Very hardy, good flesh, large eggs, good foragers.
Wyandotte ...	Yellow	Yellow or cream	Rose	Buff or brown tinted	5½—8½	Very hardy, winter egg producers, good foragers.

The chief points of economic interest and suitability for free range or confined conditions are included in Table I., the reader is referred to the Poultry Club standards for details of the Standards of Perfection.

TURKEYS

The various breeds of the domestic turkey have probably originated from the Wild Turkey (*Meleagris gallopavo*) of North America, and, curious to say, the domestic turkey, unlike the other members of the poultry-yard, is smaller than its wild progenitor.

The common-breeds most popular in this country are :—

The Norfolk Black.
The White.
The Cambridge Bronze, and the American Bronze.

The NORFOLK BLACK as a breed is practically extinct in England. The females vary from 12 to 14 lb., the males from 20 to 24 lb. The birds are fine boned, and yield fine flavoured white flesh. The legs and feet are slaty black, and the egg shells are cream coloured, speckled with brown.

The WHITE turkey is mainly an exhibition breed in Britain. The lack of hardiness associated with the English White is probably responsible for their non-success as a commercial breed in England. The females weigh from 14 to 18 lb., the males from 20 to 28 lb.

The CAMBRIDGE BRONZE is very popular among turkey breeders. They are comparatively light in bone, fatten well, and yield a white flesh of excellent flavour. The legs and feet are dark grey in colour, the eggs are cream coloured, speckled with brown. The females weigh 12 to 16 lb., the males weigh 18 to 24 lb.

The AMERICAN BRONZE is similar in character to the Cambridge Bronze, but is somewhat heavier in bone and yields a larger carcass. The flesh is said to be not so fine in quality as the Cambridge Bronze. The females weigh from 16 to 20 lb. the males from 25 to 36 lb.

GEESE

Our domesticated geese have probably all originated from the Wild Goose or Gray-lag (*Anser ferus*), which is to be found in Europe, Africa, and Asia. They generally visit this country in the winter, though some have been known to nest in the Fen districts.

Common Breeds.—The commoner breeds kept on English farms consist of the Embden and Toulouse.

The EMBDEN goose lays large white thick-shelled eggs, and is a good sitter. Their rapidity of growth and excellent flesh qualities make them very suitable for the green gosling and autumn goose trade. They are hardy and good foragers. Females attain weights 20 to 22 lb., males 30 to 34 lb.

The TOULOUSE goose is a non-sitter and a good egg layer. They thrive well on good soil, but mature slowly and are not good foragers. They are hardy and vigorous and thrive well under confined conditions, but the quality of the flesh is not as good as that of the

Embden. They are very suitable for crossing with the Embden. The females reach 20 to 22 lb. in weight, the males 28 to 30 lb.

DUCKS

The various breeds of domesticated ducks are generally believed to have sprung from the Mallard or Wild Duck (*Anas boschas*), which is to be found all over the Continent and in America, as well as in the northern parts of Africa.

The common breeds kept in this country are :—

Aylesbury	Indian Runner	Khaki Campbell
Pekin	Cayuga	Buff Orpington
Rouen	Muscovy	Blue Orpington

The chief points of economic interest are given in Table II.

TABLE II.

	Leg colour.	Type of flesh.	Egg colour.	Weight. lb.	Remarks.
Table Breeds.					
Muscovy ...	Orange-yellow	Deep cream	White	6 - 10	Poor egg layer, excellent table qualities, hardy, pugnacious, good foragers.
Rouen	Orange and Orange-brown	Deep yellow	Pale green	8—10	Excellent flesh, hardy, tame.
Aylesbury ...	Bright orange	White	White or greenish-white	9—11	Rapid growers, excellent flesh, good egg layers.
Cayuga	Orange-brown	White	Very dark green	5—7	Hardy, medium egg layers, excellent flesh.
Egg Breeds.					
Indian Runner...	Orange or tan	Orange or cream	White	4—4½	Excellent egg layers, good foragers, non-sitters.
Khaki Campbell	Dark orange			—	Excellent egg layers, good quality flesh.
Dual purpose.					
Orpington ...	Orange-yellow	Cream		6—7	Excellent egg layers, good table qualities.
Pekin	Bright orange	Yellow		7—9	Hardy, good egg layers.

POULTRY BREEDING

A farm poultry flock is generally started in one of several ways: (1) purchase of hatching eggs: (2) purchase of day-old chicks; (3) purchase of three-month-old birds, or (4) purchase of foundation stock. Which of these methods is finally adopted depends upon local and financial considerations, and farmers desiring to adopt poultry farming seriously are well advised to consult the County Poultry Instructor before finally deciding which method to adopt. In all cases, the object aimed at should be eventually to establish a healthy breeding flock to serve as the reservoir for maintaining the farm flock at the level aimed at in the scheme adopted. Apart from the personal pleasure and interest that the farmer derives from seeing evolve a farm breeding flock of desired type, the commercial advantages gained by so doing more than outweigh the extra trouble

caused by the trap-nesting, culling and egg-recording that are necessary corollaries to the evolution of an ideal breeding flock. The liability of outbreak of diseases to which poultry are susceptible is created every time purchases of outside stock are made, and many a failure of a poultry enterprise can be traced to the introduction of disease by purchase of birds from outside sources. In selecting birds for breeding; vigour, trueness to type, and freedom from disease are the main points in preliminary selection. Having made a preliminary selection of suitable birds, blood tests are carried out to ensure that the birds are not carriers of bacillary white diarrhœa, and the birds are then mated up to suitable cockerels. From a commercial egg production standpoint, rapid improvement can be effected in farm flocks by the purchase of approved cockerels bred under County or Provincial cockerel-breeding schemes. In such schemes, cockerels are bred from suitable matings made with birds which, in their pullet year, have in county egg-laying trials, put up a record of egg performance which entitles them to a special merit certificate, and owing to the precautions adopted by the committees responsible for such schemes the cockerels can be purchased with a more than reasonable assurance that they are free from disease. Annual auctions of approved cockerels take place and farmers wishing to purchase such birds can obtain particulars as to time and place of such auctions by writing to their County Agricultural Organizer. Having commenced breeding operations by rigid selection of females and the purchase of suitable male birds, the future efforts of the farmer should be directed towards ascertaining which of the birds bred possess the commercial characteristics that determine their value as potential breeding stock. Breed type and colour, size and colour of eggs, fertility, hatchability and rearability, and number of eggs required to produce a mature bird are all points of extreme importance upon which the practical breeder will require information in his desire to build up a breeding flock of proved commercial value. This information can only be obtained by trap-nesting, and keeping records of matings, incubation records and rearability records, and the egg performances, etc., of the progeny resulting from such matings. In the earlier stages, considerable progress can be achieved in flock improvement by rigid culling of females, and as indicated above, the purchase of approved cockerels of known origin, but there is a limit to the improvement that can be obtained by these means. By the progeny test, the birds which have the power of transmitting the desired characteristics to their offspring are ascertained, and the breeder should then concentrate on building up a breeding flock from such matings. Line breeding, which is a system of in-breeding, is commonly practised to impress upon the breeding stock the desired characteristics of any individual. In this case, the matings commonly used are father to daughter, father to granddaughter, father to great-granddaughter, etc., or mother to son, mother to grandson, mother to great-grandson, etc, with an occasional outcross to birds of known pedigree in order to avoid loss of stamina

that might otherwise ensue. In the limited space available to the author it is impossible to go into detail as to the recording, etc., involved in improving the breeding flock by the methods indicated, and the farmer is strongly advised to obtain such details from the County Poultry Instructor in his district. As a general rule, an ordinary hatch consists of 50 chicks from every 100 eggs set, and of these 50 chicks hatched only half reach maturity. On the assumption that half the chicks hatched are cockerels and half pullets, these considerations lead us to the conclusion that for every pullet that goes into the laying box no less than eight eggs have to be set in the incubator. By careful recording of hatchability and rearability, and by the application of the knowledge thereby gained to subsequent matings, it should be possible soon to reach the stage where the number of eggs required to be set in the incubator to ensure a mature pullet are considerably reduced, with consequent considerable reduction in the costs of producing such a pullet.

Mating.—It is usual when mating to use two-year-old hens, but mating one-year-old hens is occasionally practised if the birds are early hatched and have fully developed. Flock mating is suitable for commercial plants, *i.e.*, four or five cockerels are run together with a flock of 40 to 50 hens, but on pedigree farms the mating up of breeding pens is the usual practice. Individual mating, known as stud mating, is often resorted to in line breeding. In the light breeds, eight to fifteen hens per cockerel is the usual allowance, in the heavy, six to ten. When mating ducks the best results are obtained from two-year-old ducks mated to an early-hatched young drake, allowing about five ducks to each drake. For geese, select two- or three-year-old geese and mate to a mature gander ; three or four geese to each gander.

When mating turkeys it is very essential to select good healthy stock birds, preferably two- or three-year-old hens mated to a strong one-year-old cockerel, or, better still, to a two-year-old cock, allowing six or eight hens to each cock.

The Application of Sex-Linkage to Poultry Production.—The commercial egg farmer, particularly if he is working with light breeds, regards the cockerel as an unwanted nuisance. If we could detect the sex of the chicken at hatching time he would prefer to eliminate the cockerels at once, since they are occupying valuable brooder space and time, and when ready for market more than often represent a loss to him for the time, energy and food spent on them. Unfortunately, in the case of the pure breeds, it is impossible for him to detect the sex at hatching time, and so he has been accustomed to regard the cockerel as an unnecessary but inevitable evil. The work of Professor Punnett at Cambridge has indicated a way out of the difficulty so far as the commercial egg farmer is concerned. Professor Punnett, studying the inheritance of certain characters in poultry by Mendelian methods, found that some characters, such as silver ground colour of plumage as opposed to gold, barred plumage such as occurs in Plymouth Rocks as opposed

to unbarred plumage, and light shank colour as opposed to dark shank colour, were transmitted by a hen solely to her male offspring. The male offspring resulting from the mating of a hen carrying any of these three characters with a cockerel carrying the opposing character will be readily distinguishable from the female offspring, since the down plumage or shank colour will be different in the two sexes. Thus the cockerels resulting from the mating of a light Sussex hen with a red Sussex cock will be silver in character and the pullets will be gold, and this difference in plumage inheritance is shown in the down colour at hatching, the pullets being golden brown in colour and the cockerels creamy silver with blackish markings. Similarly, the cockerels resulting from a mating of a Black Minorca cock with a Plymouth Rock hen will be barred, whereas the pullets will be black. This again shows itself in the down colour, the cockerels being black with a whitish patch at the back of the head, whereas the pullets are entirely black. Any of the crosses indicated in the table which follows will result in chicks the sex of which can be detected at hatching. It should be unnecessary to emphasize that the cross should be made in the way indicated.

Sex-Linked Crosses.

Gold cockerels ×	*Silver hens.*
(Birds with ground colour of a buff or golden brown shade.)	(Birds, except whites, with ground colour of a creamy silver.)
Brown Leghorn, Indian Game, Barnevelders, Buff Orpington, Buff Rock, Rhode Island Red, Red Sussex, Welsummer.	Light Sussex, Silver Campines, Silver Wyandottes, Silver Hamburghs, Duckwing Leghorns, Dorkings, Salmon Faverolles.
Black cockerels ×	*Barred hens.*
Black Leghorn, Black Minorca.	Plymouth Rocks, Scotch Greys, Cuckoo Leghorns.
Dark shank cockerels ×	*Light shank hens.*
La Bresse.	White Leghorn, White Wyandotte.

By using any of the crosses indicated, except perhaps the shank colour crosses which are not so readily detectable at hatching as the others, the farmer is enabled to utilize the whole of his brooder capacity for pullets, with a resultant saving in labour and brooder capacity.

The one serious disadvantage attached to using sex-linked crosses is the inability to use the stock for breeding afterwards. This disadvantage has recently been eliminated by Professor Punnett, who has evolved a breed, the Cambar, which is sex-linked within itself. This breed, which breeds true to type, was obtained from a barred Plymouth Rock, Gold Campine cross. The female chicks are dark brown in colour, the male chicks being pale grey in colour striped with brown. Further work is being carried out to improve the commercial characteristics of the breed before it is released to the public. This breed, when available, should be of considerable value to farmers, since it will then be possible to obtain

all the advantages of sex-linkage combined with the ability to use the chicks for stock purposes at the same time.

Housing and Equipment.—A fully-equipped poultry plant comprises an incubator room, food store and office, brooder houses, laying houses and houses for the breeding flock, field equipment such as Sussex arks or movable slatted floor houses for the growing stock, and the equipment incidental thereto.

In selecting the site for the permanent buildings, the farmer should arrange to place the buildings as near to the homestead as can be conveniently arranged, particularly with regard to the incubator room and brooding equipment. If laying houses of the permanent type are to be used, particular care should be taken to site them in a well-drained field, sheltered, if possible, from prevailing winds by a shelter belt of trees.

With regard to the houses themselves, in view of the diversity of types available it is impossible within the scope of this article to deal at any length with the actual details of construction, but it is felt that the basic principles of design and construction upon which the suitability of a poultry house depend will be of value to those contemplating purchase or construction of poultry houses. A properly designed and constructed poultry house should be such as to conduce to the comfort and convenience of the poultry attendant as well as to the comfort and health of the birds themselves. From the birds' point of view, the house should be weather-tight and dry, and the floor should be free from damp. Good ventilation is essential, but such ventilation must be achieved without the production of draughts. In addition, the house should be constructed and sited in such a manner as to admit plenty of winter sunlight, while excluding the more powerful summer sun and the rain. This is achieved by facing the fronts of the houses to the south, regulating the depth and height of the house so as to correspond with the lower angle of elevation at which the sun's rays reach the earth during the winter months, and projecting the roof over the front of the house in the form of eaves to prevent driving rain from entering the house. If the height and depth of the house, and the sizes of the openings to the front of the house are properly designed, the sun's rays will reach from the front of the house to the back in the winter, whereas in the hot summer months, owing to the higher altitude of the sun, only a small portion of the floor of the house will be subjected to the direct rays of the sun. Light, removable curtains constructed of muslin or similar material stretched on light wooden frames and hung up over the open fronts of the houses, are extremely useful in keeping the houses cool in the summer, while allowing free ventilation. From the point of view of the attendant, ease of cleaning is a big consideration, the droppings boards therefore should not be wide enough to prevent easy removal of the droppings by the attendant, and the floor should be constructed of a material which can be easily and thoroughly swept clean. In the case of a large house intended to house many birds, the use of a litter carrier,

suspended from a rail running the whole length of the house, will considerably facilitate cleaning operations. In modern houses the droppings boards and perches usually used are dispensed with and a raised slatted floor substituted for roosting purposes. Slatted floors are also substituted for solid floors, and floor litter dispensed with. In such cases, the house must be constructed in such a way that sufficient head room is allowed between the slatted floor and the ground level to enable the attendant to reach under the house when the droppings require to be removed at periodical intervals. In houses of the movable or field type, the slatted floor is almost universally used, with a solid wooden withdrawable shutter underneath upon which the droppings accumulate. Protection against rats and vermin is achieved by the use of wire netting at the sides of the houses between the slatted floor and the droppings board.

Accommodation and Equipment.—The movable and fixed equipment of a poultry house consists of grain and mash hoppers, grit hoppers, roosts, water troughs, and nest boxes. The accommodation of the house itself is best measured by the floor space. Whereas crowding in a house conduces to ill health, under stocking is needlessly expensive owing to the increased cost of the housing per bird. In the case of the light breeds, 3½ sq. ft. of floor space should be allowed per bird for houses intended to house up to 50 birds, 3 sq. ft. per bird for houses accommodating above 50 birds and up to 125, 2½ sq. ft. for houses accommodating between 125 and 200 birds, and 2 sq. ft. for houses accommodating over 200 birds. In the case of heavy breeds, 1 sq. ft. should be added in each case to the figures given. Thus, a 50-bird house for white Leghorns should have a floor area of 175 sq. ft., and this house would accommodate only 38 Rhode Island Reds.

Eight inches length roost space should be allowed per bird for light breeds and 10 in. for heavy breeds. With regard to mash and grain hoppers, 1 in. of hopper space per bird should be allowed, and a 2 ft. shell and grit hopper should be allowed per 100 birds.

The nest boxes should be 12 to 14 in. square and a minimum of one nest for every six birds should be allowed. In the case of trap-nested stock, one nest for every three birds is not too much. Sitting nest boxes under the droppings boards is not advocated, as it darkens the floor area under the droppings boards and renders observations of birds resting under the droppings boards difficult.

Brooder House Capacity.—In the case of brooder houses, 6 sq. in. of floor space per chick should be allowed, and a brooder unit should not contain more than 300 chicks. Up to six weeks of age a shallow feeding trough, not more than 2 in. deep and 4 ft. long, will suffice for 100 chicks. From six weeks onwards, double this hopper capacity should be provided, and the trays may conveniently be made deeper.

Incubation.—Two systems of hatching are commonly used, *i.e.*, natural and artificial. The natural method, in which a broody hen is used, is the more economical and safer method where only small lots of chickens are being raised, or where the hatching is

strictly seasonal. The chief disadvantages attaching to the natural method is the difficulty of obtaining broody hens precisely at the time when they are required, and the fact that if a large amount of hatching is being carried out by this method, the use of a large number of small hatching units increases the amount of labour and care in management required. For this reason, except in the case of pheasant rearing and on a few well-known commercial farms, the use of artificial systems of hatching and rearing is practically universal.

Selection of Eggs for Hatching.—Eggs used for hatching should be of good parentage, clean, and over 2 oz. in weight. They should possess a good shell texture, should not be more than seven days old, should be of good shape, and free from external blemish. Eggs intended for hatching, if not immediately required for incubation, should be stored in an even temperature, preferably 60° F., and should

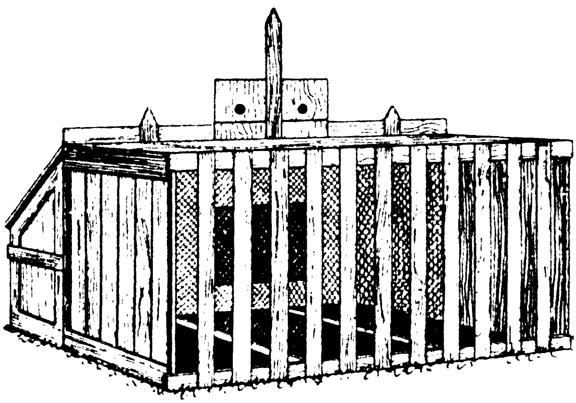


FIG 88.

be occasionally turned. If eggs purchased for hatching have travelled, they should be stored for 24 hours before placing in the incubator, in order to restore them to their natural physical condition, and to recover from the possible jolting they may have received during the journey.

PERIODS OF INCUBATION.

Fowl ...	21 days	Goose	30 days.
Pheasant	24 ,,	Swan	42 ,,
Guinea Fowl	28 ,,	Emu	42 ,,
Duck ...	28 ,,	Ostrich	42 ,,
Turkey	28 ,,		

Natural Method.—Select a suitable broody hen—one of good size and docile—the short-legged varieties, such as the Wyandottes, Orpingtons, Rocks and Old English Game being the best. The nest should be roomy—about 15 in. square, and high enough for the hen to walk off and on the nest comfortably (Fig. 88). Place some mould in the bottom and shape it out, slightly hollow

in the centre. Cover with some soft straw or hay and press into shape. Place a dummy egg in the nest and put on the hen. When she has settled down the eggs may be placed under her. A hen will comfortably cover 13 eggs and this is the usual number. It is a good plan to sit two or three hens together and test the eggs at the end of the first week, when perhaps two of the hens would take all the fertile eggs and the third could be started with a fresh batch.

They should be let off to feed each day, and should have only grain, wheat or maize, and plenty of fresh water and grit : a dust bath should always be supplied when possible. Do not meddle too often with hens when hatching for they are apt to get peevish and will crush the chickens as they are just hatching. Before removing to a coop (Fig. 89) the hen should have a good feed of corn, and when the chickens are fed she will call them to the feed instead of taking it herself.

Artificial Method.—Hatching eggs by means of artificial methods has long been practised in Egypt and, although of comparatively recent introduction in this country, the incubator has been used with commercial success for upwards of 50 years. The incubator

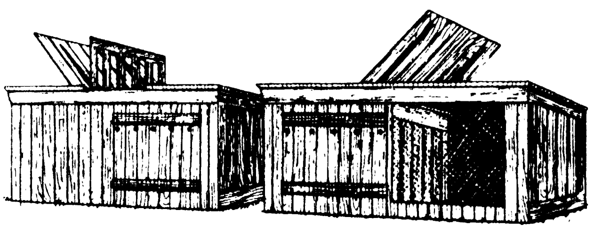


FIG. 89.

is essentially a heated insulated box designed to maintain the eggs placed in it at a temperature approximating that of the natural heat supplied by the broody hen. The capacity of modern incubators varies from a 25-egg capacity to a capacity of many thousands. Incubators fall into two main classes, those in which heated air is used, and those in which radiation of heat from a hot water tank is employed to maintain the eggs at the required temperature. Owing to the fact that the hot water acts as a heat reservoir, the hot water type of incubator is in general favour for small incubators, since a steady temperature is more easily maintained in spite of a fluctuating source of heat, but in the larger types hot air in conjunction with fans and baffle plates to maintain adequate ventilation and even distribution of heat is generally, though not always, employed. The fuel used as a source of heat consists of oil, gas, electricity and anthracite coal. Since the method of use and management of an incubator varies with the type used, and since such instructions are issued by the manufacturers with each incubator sold, it would be waste of time to describe the working of an incubator here in any detail. For this reason it is proposed to outline the principles upon

which successful incubation depends, since it is generally through neglect of observation of these principles, and not through inherent faults in the incubators themselves, that bad or faulty hatches generally result.

Conditions for Successful Incubation.—The conditions upon which successful incubation depend are :—

(1) Maintenance of an adequate and even temperature.
(2) Maintenance of the right amount of moisture or humidity.
(3) Maintenance of adequate ventilation.
(4) Avoidance of stuck germs by adequate turning of the eggs.

With regard to temperature, the temperature of a broody hen varies from 101° to 106° F., with an average temperature of 104·5° F. Based on the temperature of the broody hen, the incubator temperature should therefore lie within 101° to 106° F., and it should never be allowed to exceed these limits. Owing to the development of internal heat by the developing eggs themselves, the regulation of the incubator temperatures should be carefully attended to particularly in the later stages of incubation, since there is a danger of the incubator becoming too hot at this period. Observations have shown that in natural incubation there is a difference of temperature between the upper and lower surfaces of the egg of as much as 18° F., and the earlier incubators were designed in such a way as to ensure that the lower surfaces of the eggs were maintained at a temperature considerably less than the upper surfaces, but experiences in incubation with modern incubators of the mammoth type have shown that there is no need to make provision for this.

Ventilation.—The developing egg, being a living organism, requires oxygen for its development, and in developing gives off carbon dioxide gas. For this reason, adequate ventilation must be provided. In small incubators the natural convection currents set up by the heated air of the machines, combined with a suitable design in the construction of the machine itself, serve to maintain adequate ventilation. In the larger incubators, fans are used to achieve the same purpose. During the first day of incubation, an egg uses up 4 c.cs. of oxygen, and this rapidly increases as incubation proceeds, until on the 21st day no less than 555 c.cs. of oxygen are required. To provide for the oxygen required, it is obvious that constant supplies of fresh air are required, and that this becomes of increasing importance as incubation proceeds. Not only is ventilation necessary to supply the oxygen required, but it is also required to get rid of the carbon dioxide given off by the developing eggs. Experimental tests have shown that if the carbon dioxide in the incubator goes above 1·5 per cent., high mortality results.

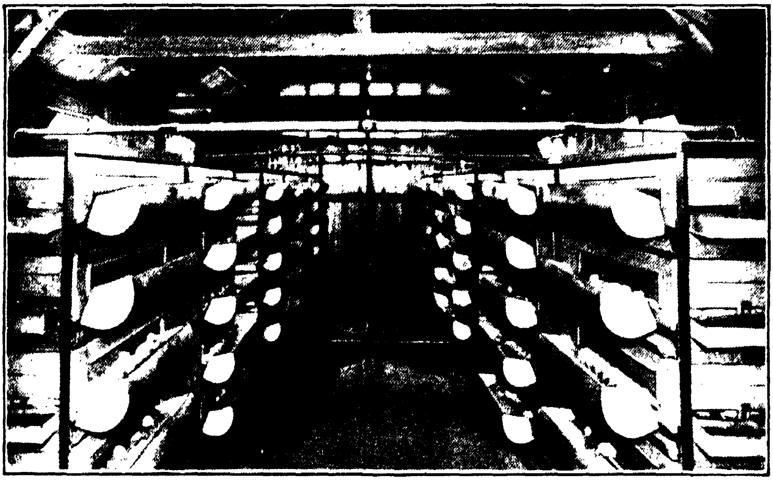
Moisture or Humidity.—Everyone is familiar with the fact that

air contains variable proportions of moisture in the form of an invisible vapour, the amount present varying according to weather conditions. The ratio between the amount of water vapour present in a given volume of air and the amount required to saturate it is called the relative humidity. The actual amount of water vapour present in the air is called the absolute humidity. Since the amount of water vapour that dry air will take up varies with the temperature of the air itself, it will be seen that for the same absolute humidity the ratio between the relative humidity and the absolute humidity will differ at different temperatures. Now eggs exposed to dry air lose water by evaporation, the dryer the air the more the loss of water in a given time. In order that eggs may develop successfully, the maintenance of a certain moisture content is essential. If the air reaching the eggs in the incubator is too dry, the eggs will lose too much water and death will result. On the other hand, if the air is too moist, not enough water will evaporate and the developing chicks will, as it were, be " drowned." The maintenance of the right humidity is therefore important and experimental observation on incubation has shown that it is the relative humidity rather than the absolute humidity that matters. It has been shown that if the relative humidity falls below 30 per cent. or rises above 60 per cent., eggs fail to incubate successfully. In normal practice there is more danger of the relative humidity falling below 30 per cent. than rising above 60 per cent., so the practice of raising the humidity of the air in the incubator room itself by frequently sprinkling the floor with water or by the employment of wet sand in trays is a good one. In the incubator itself, the humidity is usually maintained at the right level by the use of water tanks and wet flannel, or in the case of large incubators, by the use of water sprinklers or similar devices. The use of hygrometers or humidity meters in both the incubator room itself and the incubator is therefore essential if regularly successful incubation results are desired.

Turning.—The question of the necessity of turning the eggs at frequent intervals during incubation is a more debatable point than those already dealt with above, but in view of the danger of incubation being interfered with if the eggs are left in one position throughout incubation owing to the possibility of germs sticking to the shell, the practice of turning the eggs at least twice a day is probably a sound one.

The Incubator Room.—The maintenance of the requisite conditions for successful incubation in the incubators is more easily achieved if care is taken in the construction of a suitable incubator room, or in the selection of a suitable room or shed in the existing farm buildings. The ideal incubator room should possess adequate ventilation without draughts, should be designed so that a relatively high humidity may be maintained, and should be well insulated so that the room temperature is not readily affected by changes in temperature in the outside surroundings. A brick cellar with earth or cement floor forms an ideal incubator room, and will generally

PLATE XV.



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only need slight structural alterations so as to ensure adequate ventilation.

Rearing.—The rearing of chickens divides naturally into two periods : (*a*) the brooder period, when chicks require supply of heat : (*b*) the "growers" period, *i.e.*, from end of brooder period to maturity. Under the natural rearing system, where broody hens are used, broody coops out in the fields form all the equipment necessary. In rearing by artificial methods, more elaborate equipment is necessary. In such methods, the chicks are reared in units varying from 50 to 500 chicks each. The chicks are housed in suitable brooder houses. A typical brooder house has a feeding passage running along the back, and the house is divided into pens. Each pen contains a hover which supplies the heat necessary to maintain the chicks in comfort during the brooding period. The heat is supplied in some cases by paraffin lamps, by hot-water pipes heated with anthracite, or by electricity. In some cases, where chicks are raised in units of 300 to 500, a separate brooder house is used for each lot of chicks, and the hover consists of an anthracite stove with a round galvanized cone fitted above the stove to radiate the heat down on to the chicks. In big commercial plants battery brooders are used. Battery brooders consist of series of metal cages arranged in tiers one above the other and heated by hot-water radiators. The chicks are kept in such brooders for three to four weeks, being moved down a drawer at a time each week. The temperature in the top tier of drawers is maintained at about 85° F., the temperature in the lowest tier being approximately 65° to 70° F. From four weeks onwards the chicks are kept in cooler cages which are maintained at a temperature of approximately 60° F. (Plate XV.).

Whatever the system of brooding adopted, the aim of the rearer should be to cool the chicks off gradually by reducing the temperature of the hover or brooder until at six to eight weeks, according to season, the heat may be dispensed with altogether.

As soon as can be arranged conveniently after eight weeks of age, the chicks are moved out into Sussex arks until full grown. Cockerels surplus to requirements are fattened and sold as soon as they reach a convenient marketable age. In the case of the light breeds, such as Leghorns, these should be marketed as petits poussins.

Feeding.—Poultry foods consist of cereal grains and cereal grain bye-products, supplemented with protein-rich substances of animal and vegetable origin, mineral salts and vitamin concentrates, and green foods.

Systems of Feeding.—Poultry may be fed on grain, grain and wet mash, grain and dry mash, grain and wet and dry mash, or on mash only. All these different systems are in use, but the general concensus of practical opinion is veering round to the use of dry mash for chicks during the brooding period followed by dry mash and grain feeding for growers and adult stock. For winter egg production, a mid-day feed of wet mash is often given.

The Use of Grit.—The digestive system of the fowl is so constructed as to enable it to deal efficiently with grains and hard foods. The crushing of the food into fine material that is accomplished in other animals by means of teeth is effected in the bird by means of the gizzard, a strongly muscular organ. The gizzard is aided in this task by the numerous small stones that are invariably found in it when a bird is killed and the gizzard opened. There has been considerable difference of opinion among poultry keepers for the last 200 years as to the need for supplying grit, this difference of opinion being due to the fact that whereas certain poultry keepers have found it possible to rear healthy chickens without supplying grit others have found it impossible to do so. Recent research has shown that unless grit is present in the gizzards of birds, the food, especially grain, is not fully digested. The difference referred to above is really due to the fact that under certain conditions, as when birds are kept on gravelly soils or loams, the birds pick up from the soil all the grit they require to keep them in perfect health, whereas if the birds are kept on heavy clay land the lack of grit sooner or later manifests itself in ill health of the stock and possibly crop binding. Even in the latter case, if the food supplied is in the form of a mash, the birds may thrive quite successfully for some time even though grit is withheld. From the point of efficiency of digestion of the food and maintenance of a healthy muscular tone of the digestive system, there is, however, little doubt that the supply of suitable grit to birds of all ages is sound practice, even though the birds may be kept under all-mash conditions. Such grit should be of the insoluble variety, such as flint grit or suitably screened river gravel.

Chick Feeding.—The nature of the food mixtures used for chick feeding depends largely upon the conditions under which the chicks are reared. Under free range conditions, rearing with a broody hen, feeding with boiled wheat only with milk to drink has led to successful results, whereas under battery brooder conditions a relatively complex mash is necessary for efficient nutrition of the chicks. Under typical farm conditions, when the chicks are raised during the spring or early summer months and have access to an outside grass run, a grain diet consisting of equal parts by weight of split wheat, split groats and maize grits will suffice for the first week, supplemented in the second with a dry mash fed in hoppers consisting of bran 2 parts, middlings 4 parts, Sussex ground oats 2 parts, maize meal 1 part and fish meal 1 part will give good results, particularly if fresh skim milk is available in addition. The first feed may be given at any convenient time after the down feathers have dried out, and a common practice is to feed only bran and fine sand as the first feed. Grit and fine oyster shell should also be available in suitable hoppers. At eight weeks the birds are put on to a grower's mash consisting of bran 3 parts, middlings 4 parts, Sussex ground oats 2 parts, maize meal 1 part, fish meal ½ part, and the grain feed consists of equal parts of wheat and

kibbled maize. If, however, the chicks are reared in brooders under intensive conditions, or during the winter months, a more complex system of rationing is necessary. In such conditions an all-mash system is generally used, and the following mash advised by the National Institute of Poultry Husbandry, has proved successful for feeding from one to ten weeks.

Maize meal 48 parts, bran 14 parts, middlings 14 parts, extracted soya bean meal 6 parts, dried skim milk 6 parts, meat and bone meal 6 parts, salt 1 part, cod liver oil 1 part, limestone flour 2 parts, steam bone flour 2 parts. Grit and fresh water should be always available. From eight weeks onwards, the feeding for growers indicated above will suffice.

In the case of battery-reared chicks, a more complicated mash still is indicated, and the following mash can be recommended for this purpose for the first eight weeks :—

Maize meal 33, bran 14, middlings 23, Sussex ground oats 5, dried skim milk 7, fish meal or meat and bone meal 7, dried yeast 3, linseed meal 3, limestone flour 2½, salt ⅜, ferric oxide ⅛, cod liver oil 2.

An occasional sprinkling of fine flint grit and wood charcoal is placed on the top of the mash in the hoppers and towards the end of the fourth week a little wheat is given in addition to accustom the birds to grain feeding. At the age of 11 weeks, when the birds will be out in Sussex arks, the feeding consists of grower's mash and grain, the grain mixture used being wheat 3 parts and kibbled maize 2 parts. The change over from the chick mash to the grower's mash should be gradual, *i.e.*, during the ninth week the mash should be a mixture of 3 parts chick mash to 1 of grower's, followed by equal parts in the tenth week, 3 parts grower's to 1 of chick mash in the 11th week, so that in the 12th week the birds are entirely on grower's mash. The grower's mash is continued until the combs begin to redden up, when the birds are put on to layer's mash.

Feeding for Egg Production.—Correct management is just as important, if not more so, than correct feeding if satisfactory egg production is to be expected. The provision of adequate hopper space, regularity in feeding and cleaning, and adequate supplies of water and grit, and avoidance of any causes likely to disturb or unduly excite the birds are all points of primary importance in successful egg production. The usual method of feeding consists in the use of dry mash feeding combined with grain feeding. ½ oz. of grain per bird is generally fed first thing in the morning and 1½ oz. about half-an-hour before roosting. Green food, if given, is supplied in the middle of the day. The dry mash hoppers are left open all day. Grit and oyster shell are provided in separate hoppers. During winter months, egg production is encouraged by giving a wet mash feed once a day, 1 oz. of mash (weighed dry) being allowed per head. One per cent. of cod liver oil added to the mash will also be beneficial, and if electric light is available, lighting the pens so as to extend the working day will increase the level of egg production. If green food is not available, alfalfa meal is generally included in

the mash to the extent of 5 per cent. in order to maintain a satisfactory egg-yolk colour. A satisfactory layer's mash consists of bran 15 parts, middlings 40 parts, maize meal 22½ parts, Sussex ground oats 10 parts, fish meal 12½ parts. The grain ration consists of wheat 3 parts, kibbled maize 2 parts, fed at the rate of 2 oz. per day.

Breeder's Mash.—For breeding stock, the mash is the same as for layers, but the 12½ parts of fish meal are replaced by 7½ parts fish meal, 2 parts of cod liver oil and 3 parts dried yeast, with a view to ensuring high fertility and hatchability of the eggs produced.

Fattening Mashes.—A good fattening mash for trough feeding consists of meat and bone meal 5 parts, dried milk 5 parts, maize meal 30 parts, middlings 30 parts and barley meal 30 parts, fed as a wet mash. If ample supplies of skim milk are available this can be used instead of water for making the wet mash, and in such circumstances the dried milk would, of course, be omitted. Where young cockerels are being fattened this mash should be used instead of the grower's mash when they change from the chick mash.

Ducklings.—These only require a little heat for the first ten days or two weeks in cold weather. The food should consist of barley meal, pollards, and maize meal, mixed to a crumbly paste with milk for the first six weeks; the remaining four weeks they should be fed on rice cooked in milk and mixed dry with pollards and oatmeal. Sufficient water should be supplied for drinking purposes only, and some grit should be placed in the bottom of the drinking vessel. They should have plenty of green food and boiled vegetables, as this tends to keep them healthy and is cooling to the blood. They should be ready to kill at ten weeks old—that is, before they begin to moult. It is a good practice to allow them to swim in a pond about two days before they are killed, so that they may clean their feathers.

Geese.—Young goslings require very little artificial food, as they consume a considerable quantity of grass. A little boiled wheat mixed dry with barley meal is a good food to give them a start. They should be placed in a large roomy coop with a run in front for a few days. The coop should be bottomless and placed in the shade, for the young goslings do not thrive so well when exposed to the direct rays of the sun. They should not be allowed to swim for the first two or three weeks, unless the weather is very warm.

If required for the Michaelmas trade, they should be kept in good condition, and should have a morning meal of barley and maize meal, and oats at night; but when required for the Christmas trade, one feed of corn in the evening is all they require to keep them in good growing condition. They should never be allowed into a stream, as fighting against the current when going up-stream tends to harden the muscles and makes them very tough.

Turkeys.—For the successful rearing of young turkeys it is essential to have good, clean, well-drained land, with short grass, large, well-ventilated houses, and good sound food.

The first feed should be given when they are twelve hours old, and should consist of hard-boiled eggs, chopped fine and mixed with breadcrumbs. This should be dropped right in front of the young birds, so as to attract their attention. Skim milk should be given to drink, and plenty of chopped green food, such as onions and dandelions. After the first week discontinue the egg food, and gradually change the food to ground oats and pollards mixed to a crumbly state with sweet skim milk, and plenty of green food. They require very close attention during the first two months, and must be protected from wind and rain till they have "shot the red," which is the appearance of the red growths on the head. After this they become much hardier, and their appetites increase enormously. They must be kept growing, and given a good range, for they are splendid foragers. About a month or five weeks before Christmas they should be placed in a dry shed and fattened, the food to consist of barley meal, ground oats, and pollards, mixed to a paste with skim milk for morning feed, and oats and barley and wheat in the evening. They should always have a good supply of sharp grit and fresh clean water.

Diseases.—So far as poultry are concerned, prevention of disease rather than cure should be the object aimed at. Since it is impossible to deal at length with all the diseases that attack poultry, this article deals only with a few considered of major importance. Poultry are subject to attack by external parasites, such as lice, fleas, bugs and mites, and by internal parasites such as mites, roundworms and tapeworms, flukes, fungi and bacteria.

Lice.—These are biting creatures, which belong to the Mallophaga, and live by eating fluff, feathers, skin scales and any dried blood that may arise from the injuries produced. Infected birds may be detected by manual examination. Lice are confined to the body of the bird, and their favourite locations are the head and neck, the slightly feathered portions of the body, and the lower side of the wing feathers, the actual location varying according to the species, of which, according to Bayon, there are no less than 40 to 50. The eggs or nits are found attached to the feathers. Owing to the attachment to the host, their eradication is comparatively easy. Clearing and burning of the contents of the nest boxes, and powdering the birds individually with a small pinch of sodium fluoride, well rubbed in, will suffice to rid birds of these pests. Owing to the irritating nature of this compound, special care should be exercised by the operator in its use, and where possible the substance should be used in solution form rather than as a powder. In such cases, the birds are plunged into a warm bath of water to which ¾ of an oz. of fluoride for every gallon of water has been added.

Fleas.—Fowl fleas, unlike fowl lice, live by sucking the blood of the host, and owing to the fact that they are not confined to the body of the host and can survive for months in the absence of food, are difficult to eradicate. The eggs or nits are usually found attached to pieces of nest material. Treatment consists in strict

attention to hygiene, consisting of frequent replacement of nest material, destruction of the old material and litter, etc., around the nest boxes, creosoting of the nest boxes, and sodium fluoride treatment of the individual birds.

Mites.—The mites of chief importance in this country are red mites, feather mites, scaly leg mites, and the depluming scabies mite. The red mite is a blood sucker, is a night feeder, and lives, not on the host, but in cracks and crevices of the fowl houses. The eggs are laid in the crevices, or in dust, dry droppings, etc. It is a difficult pest to eradicate, and treatment, which should be persisted in, consists of thorough creosoting of the houses, frequent renewal of the nest box material and floor litter, and frequent cleaning of droppings boards. Special attention should be paid to the method of fixing the perch ends, and devices should be used that will act as mite traps.

The feather mite is similar to the red mite, but lives on the host and is therefore more easily dealt with. The same treatment advocated for red mite should be adopted in case of attack.

The scaly leg mite lives in the deeper layers of the skin, usually on the legs. In case of attack, the legs become enlarged and covered with unsightly roughened greyish patches. Treatment of the legs with commercial paraffin and vaseline will quickly eradicate the disease.

Depluming Scabies Mite.—This disease affects birds during spring and summer, and is characterized by the appearance of raw red patches bare of feathers. Owing to the irritation caused by the mite, feather-picking results in affected birds. Treatment by sodium fluoride dip is the best treatment, and will quickly get rid of the trouble.

Roundworms.—Gapeworms, the large fowl ascarid, and the cæcum worm, are the chief roundworms that cause trouble in poultry. The gapeworm lives in the windpipe, and is a common disease in young chicks. Affected chicks gape, and frequently give a curious little rasping cough. The disease is readily conveyed through infected ground. Treatment consists in segregating the affected birds, removal of healthy birds to fresh rearing ground, and avoidance of rearing grounds on which the disease is known to occur. By means of a feather dipped in equal parts of olive oil and turpentine and carefully passed into the windpipe, most of the worms may be removed, or persuaded to loose their hold on the windpipe sufficiently to enable affected birds to cough them up.

Cæcum Worm.—This worm, which is fine and threadlike and about ¼ in. long, occurs in the chicks in the cæca, and leads to the appearance of unthriftiness in affected birds. The birds affected should be isolated and kept on wire screens so that the voided droppings may be removed and burnt. Bushnell and Bradly recommend injecting a solution made up of 1 drachm of oil of chenopodium in 6 oz. of olive oil, which solution is passed into the

lower bowel by means of a blunt syringe through the vent passage, repeating the treatment at the end of five days.

Large Fowl Ascarid.—These roundworms are 2 to 3 in. in length, and are commonly found in the small intestines of affected birds, infection of which is characterized by unthriftiness and often diarrhœa. Treatment in adult birds consists in giving a 4 c.c. capsule of carbon tetrachloride after keeping without food over night, and feeding with mash until the dead worms are voided. The droppings from such birds should be collected and burnt.

Tapeworms.—About 25 varieties of tapeworm are known to infect poultry, and since these creatures need an intermediate host to complete their life cycle, treatment consists in taking precautions to prevent the birds from picking up the infected hosts. In England, slugs are the commonest creatures known to act as carriers of this disease. Affected birds should be isolated, and treated with wet mash in which Epsom salts has been mixed. The usual dosage is 1 tablespoonful of salts mixed with every lb. of mash (weighed dry). Anæmia in birds is a characteristic symptom of infection with tapeworms. If, after Epsom salt dosage, tapeworms are detected in the droppings, 1 to 2 grain capsules of thymol should be given at five-day intervals until the droppings become free from this pest.

Coccidiosis.—This disease is characterized by white diarrhœa and the droppings become tinged with blood, particularly in advanced cases. Birds affected with this disease are unthrifty in appearance, and in the case of young chicks heavy losses occur through deaths. The micro-organism responsible for the disease lives in the intestines and damages the internal lining. Treatment consists in killing the affected chicks, followed by rigorous sanitary measures, such as burning all litter and refuse, and thorough disinfection of the brooders and other appliances. Care should be taken to avoid the transference of suspected birds to fresh rearing ground, owing to possible contamination of the ground.

Bacillary White Diarrhoea.—This disease, which causes heavy losses in brooder chicks, is characterized by diarrhœa and pasting of the vent, and is often confused with coccidiosis. Heavy losses among newly hatched chicks, associated with diarrhœa, should immediately give rise to the assumption that this disease is present. On confirmation of the disease by competent disease specialists, the entire batch of birds, both affected birds and healthy ones, should be killed and burnt, and the brooders and incubators thoroughly disinfected. The disease is carried on from generation to generation by infected survivors who, though apparently healthy, are heavily infected. The infection is carried through the egg by such carriers. Treatment consists in prevention rather than cure, and this prevention is obtained by clearing out of the flock the carriers of the disease. By submitting a sample of blood obtained from an adult bird to a recognized veterinary laboratory, it is possible to state whether the bird is a carrier of the disease or not. Such

carriers should be immediately removed from the flock, killed and disposed of. The flesh from such birds is quite edible and may be used for human consumption.

Avian Tuberculosis.—This disease occurs in adult stock, and is characterized by wasting or going light of the affected birds. Pigs can act as carriers of avian tuberculosis, a fact that should be constantly borne in mind by farmers keeping both pigs and poultry. Examination of the carcass of an infected bird will reveal the occurrence of typical tuberculosis lesions in the internal organs. Where the disease is present, the avian tuberculin test should be carried out, all reactors removed and destroyed and burnt, and the houses thoroughly disinfected. The healthy stock should be removed to fresh ground for a year or two, and neither pigs nor poultry should be allowed on the infected premises.

Fowl Pox.—This disease is characterized by the appearance of wart-like growths on the comb and wattles, eyelids, and other parts of the body, which growths after a fortnight or so form scabs which eventually fall off. Treatment consists in applying a solution of pigeon pox virus to all the birds in an infected flock. The solution can be obtained from the veterinary laboratory of the Ministry of Agriculture, together with instructions as to method of application.

Diseases caused by Fungi.—Two diseases due to moulds occur in poultry, favus or "white comb," and aspergillosis. "White comb" is characterized by the appearance on the comb and wattles of greyish spots which gradually spread and may, in bad cases, involve the neck feathers. It easily spreads from fowl to fowl. Treatment consists in isolation of the infected birds, removal and destruction of litter and treatment of the affected skin areas by painting with tincture of iodine. Aspergillosis affects mainly young chicks, and arises from damp conditions in the brooder house, or from the use of straw or food containing the spores of the mould responsible for the disease. The fungus grows in the lungs and lung passages, and causes pneumonia resulting in the death of the chicks. The disease shows itself on post mortem examination as greenish or greyish-green patches, in which the actual fungus may be detected by microscopical examination. Treatment consists in thorough disinfection of appliances, replacement of both litter and food by fresh, sound material, and avoidance of conditions conducing to abnormal humidity. An outbreak of this disease has been traced to the use of a disused greenhouse as a brooder house.

General Observations.—Although the list of diseases dealt with in this article appears formidable, they are not likely to arise if the following hygienic rules are rigidly carried out as a regular routine :—

(1) Regular disinfection and cleaning of all poultry appliances.

(2) Frequent replacement of all litter and nest-box materials by clean, sound materials.

(3) Use of sound mash and grain only of good quality.

(4) Isolation for a month of all purchased stock and stock returned from shows before allowing them to mix with the farm flock.

(5) Refusal to obtain hatching eggs from other than a known reliable source, obtaining such eggs preferably from stocks blood-tested for bacillary white diarrhœa.

KILLING AND DRESSING

Killing.—There are many ways of killing a fowl, but the most humane one, as well as the quickest and cleanest, is to dislocate its neck, as no blood is seen. The bird should be taken by the legs in the left hand, which can grasp the ends of the wings also; take the head in the right hand. Place the legs against the left hip and the head over the right thigh. Draw the fowl to its full length, and at the same time turning the head suddenly backwards, the neck becomes dislocated just below the junction with the head. There will be a certain amount of muscular contraction and some fluttering, but if the operation is properly carried out there is no pain. Plucking should commence as soon as the bird is killed, for a bird is much easier to pluck while warm. When this operation is completed, the birds are placed on a shaping-board (Fig. 90) breast downwards, with a board and a weight placed on their backs, and left till cold. This greatly improves their appearance, making them look much plumper than they did before.

FIG. 90.—SHAPING-BOARD.

Dressing and Trussing.—All that is required is a good knife, a trussing-needle (about 10 in. long), and some fine strong string.

The birds should be singed to get rid of the hair, using straw or grease-proof paper, so that there will be no smoke to discolour the skin. They are then wiped over with a dry cloth.

Lay the chicken on its breast, take the skin where the neck joins the body in the thumb and first finger of the left hand, and make a transverse cut, exposing the neck. Cut off the neck just where it joins the body, leaving about two or three inches of skin in front; now turn the bird breast upwards, and take out the crop. Insert finger in $\wedge$-shaped opening, and, loosening all the internal organs which can be reached, turn the bird on to its breast, stern upwards, and make a cut between the tail and the vent and an angular cut on each side of the tail (this prevents the skin splitting when the bird is being drawn). Insert the finger and find trail, pass the knife under loop, and cut off the vent.

Loosen the fat from the gizzard, and then, by taking hold of this

and drawing gently, the whole of the intestines, with the liver, heart, and lungs, will come away in one mass. Cut off the extreme tips of wings and feet, and nick the skin in front of and an inch above the hocks. Place the needle through the leg and body and out through the leg on the other side, and back through the wing over the back, and through the wing on opposite side; pull tight and tie. Pass the needle through body at end of back near the tail over the leg, through the skin under the breastbone, and over the other leg, and tie tightly. Smooth the fowl over, and the operation is complete.

Ducks are generally killed by breaking the neck, as described for the fowl, plucked, singed, and wiped over with a cloth.

Cut off the neck where it joins the body, leaving about two inches of skin to fold over stump. Then place the bird in a basin and pour boiling water over the breast and feet (this tightens the skin and makes the bird look a great deal plumper). Lift the bird out of the water and wipe dry, then strip the hard outer skin off the legs and feet and remove the nails. Place the bird on its back, and with the second finger of the right hand loosen all the internal organs (as in the case of the fowl). Turn the bird round, make a transverse cut below the tail, insert finger and find trail, which is cut off.

Loosen the fat from the gizzard, and then, by taking hold of the gizzard and pulling gently, the whole of the intestines, with the liver, heart, etc., will come away in one mass.

Cut off the wings at the first joint, stitch the neck skin over stump and tie the wings across the back with tape. Press the feet inwards and downwards, so as to bring them under the thighs, and hold them in position. Then place the giblets—*i.e.*, the neck, heart, liver, gizzard, and wings—into the body of the bird. Pass the tail through the hole where the vent is, cut out and tie the legs across the back with tape. Lay any fat which is taken out of the bird over the breast, and place on a slate slab to cool for a few hours, when it will be ready for market. Never pack ducklings whilst they are warm, because they discolour so quickly. They should always be allowed to get cool and firm before packing.

Geese.—The best method of killing a goose is to give it a sharp blow on the head with a stick to render it unconscious, and then cut across the base of the skull with a sharp knife.

Geese are dressed in the same manner as described for ducks.

Turkeys.—The best method of killing a turkey is to fasten its legs with a strong cord, and by this cord suspend it to a beam head downwards at a convenient height for the operator to pass his left arm round the bird's body. Take its head in the right hand, extend its neck to the full length, and give a strong jerk downwards, at the same time turning the head upwards. The neck is dislocated just below the junction with the head, and death will be instantaneous. There will be some muscular contraction, but no further pain.

Turkeys are dressed in the same way as fowls, though it is usual to remove the merrythought, so as to allow of a better cut of breast and forcemeat when carving.

PRESERVATION OF EGGS

Eggs for preservation should be treated as soon as possible after they are laid, or as soon as they have cooled. Infertile eggs are likely to keep better than fertile ones.

The best months for preserving eggs are March, April, May and June, and these are the months when the eggs are most plentiful.

The best results are obtained when the eggs are stored in a cool place.

The following are the common methods of preserving eggs :—

I. Water glass (silicate of soda).
II. Lime water.
III. Salt.
IV. Fat or Butter.

Water-glass is now one of the most popular methods of preserving eggs. A concentrated solution may be purchased at all chemists and stores, and it is very easy to prepare. A 10 per cent. solution is generally employed though experiments have proved that a 5 per cent. solution gives very good results. It will mix better with hot water, but the solution must be quite cold before putting in the eggs. Take care to see that all the eggs are sound when putting in. If any are cracked, they may spoil the whole batch. See that the solution covers the eggs to a depth of about 2 in.

Lime Water.—This is one of the oldest methods of preserving eggs, and it has the advantage of being very cheap. One gallon of lime (slaked) is mixed with a quart of salt and added to five gallons of water, and thoroughly mixed and allowed to stand for a few days. The clear liquid is drawn off, and this is poured over the eggs so as to completely cover them. A cloth is placed over the top, just touching the water, and into this cloth some fresh slaked lime is put, so that if the lime in the solution loses its effect, more can be taken up.

When the eggs are taken out of the solution they require very careful handling, as the shells are very brittle, and they are also very rough.

Salt.—Eggs can be preserved in salt by placing about 2 in. of salt in a jar or case and laying the eggs in the salt with the broad end down. Cover with a 2-in. layer of salt, and another layer of eggs, and so on, till the case is full. The one objection to this method is the increase in the air space, which gives the eggs the appearance of being stale.

Greased Eggs.—This method consists of coating the eggs with a thin layer of fat or butter. Take a small piece of butter in the palm of the left hand, and with the right hand turn the egg round several times, so that it gets a thin coat of butter all over the shell, thus closing the pores and preventing evaporation of moisture. The eggs are then stored, with the broad end downwards, on shelves. Care must be taken that the butter is of good flavour, or the contents of the egg will become tainted.

CHAPTER XXV.

ANIMAL PRODUCTION.

THE main place of the animal in agriculture (apart from work) is to consume crops which cannot be used for human consumption direct, and so manufacture from them an article fit for human consumption. Where the climate and soil are good and will produce good corn crops which ripen well, as in the south and east of Great Britain, the animal does not play such an important part in agriculture as it does in the north and west, where the crops grown do not mature so well, and consequently are not so fitted for human consumption. Thus as one goes to colder climates with less sunshine, and to wetter climates where ripening is delayed, the animal becomes more and more important in agriculture. Similarly when, as at the present time (1932), the prices of corn are low, pigs and poultry, which consume grain foods similar to those consumed by man, can be used with profit to cash and reduce the surpluses of these otherwise almost unsaleable products.

The climate and soil will also, through the general effect on the chemical nature of the plant products, determine the nature of the animal product it is most profitable to produce. In the early stages of growth the plant contains a high proportion of protein; with growth formation of carbohydrates takes place, and sugar and starch accumulate; while later, as the flowering stem is formed, these are turned into lignified cellulose, and most of the remainder is translocated to the seed. Thus there are three main stages in the life of the plant—protein, carbohydrate and fibrous. Now where the climate is cool or the soil damp, or both, this process of change is delayed in time, and the grazing season is long; while under the opposite conditions it is speeded up and the grazing season is short. Consequently, we find that in cool, moist climates and places pasture land predominates; while in hot, dry climates arable land is prevalent, for by this means water is conserved and crops can be grown at different seasons in succession. Thus it is in the north and west, with areas of high rainfall, that a protein food suitable for milk production and growth is most easily produced, and cattle are merely reared and then sent to the Midland grassland area, which has a lower rainfall and higher sunshine and so higher carbohydrate production, for fattening in the summer, and to arable districts of the east (Norfolk) for fattening off on roots in the winter. There are, of course, many exceptions to this general statement due to other causes operating, but the above-mentioned outline shows the main trend of cattle production which has been found by experience to be economic on the large scale in this country. Similarly, as regards milk products—excluding the sale of fresh milk, which is protected (by its perishable nature) from outside competition, and is so outside the pressure of these economic forces. With cheese and condensed milk, where the chief product is the proteins, we find that it is the grassland districts of the west

which can produce it most economically (and, moreover, the quality of the cheese is better when made from grass), while when the fat as butter or cream is the main consideration, then districts bordering on those suitable for fattening, *i.e.*, with sunshine and shower—the Channel Islands, Devon and Cornwall, and formerly districts in Suffolk—are the most favourable.

Where a product can be sold in the fresh condition for direct consumption (such as pork or fresh milk), it is usually more profitable than one which has to undergo a manufacturing process first (bacon, cheese, butter); but the market for the former is limited and often seasonal (pork meets with a smaller demand in the hot weather), so that the latter act as safeguards in times or seasons of over-production, and in places where the costs of production are low, may form the primary product. Where an article such as bacon can be produced largely from the by-product (skim milk, whey, etc.) of another article such as butter or cheese, it can compete favourably with the same article produced as a primary product, for at times of unfavourable prices it can be sold at cost price, and the market kept, if the other product is selling well. Similarly, a system of farming where sheep or bullock fattening is associated with corn (barley) growing on poor soils, the manurial value of the animal when the crop value is high will allow of low production costs for mutton or beef, whereas when the price of meat is relatively high the profits on this will allow of low costs for the production of corn. Thus by such a system the business of farming is stabilized.

Fertility and Sterility.—The structure and functions of the reproductive organs have already been described (see p. 454). Fertility is controlled for the most part at three main stages in the process of reproduction: (*a*) The number of ova or eggs which are produced by the female at each heat period; (*b*) the number of these eggs which get fertilized; and (*c*) the number of these embryos which develop up to the time of birth.

(*a*) The number of eggs which ripen in any given species is determined by the amount of some substance or substances circulating in the blood rather than by the structure of the ovary, for when one of the ovaries is removed (*e.g.*, in a pig) the number of young born in the litter is the same as in the normal animal. The chemical nature of the substance has not yet been determined, but it has been found that it is secreted by the anterior pituitary, a small gland at the base of the brain. This substance is also probably used up in growth and in lactation, so that the young animal when growing rapidly does not come on heat and breed; but as soon as growth, particularly of the long bones, begins to slacken, then this substance would appear to become available, and the animal becomes sexually mature. For a short time after this (age of puberty), and before growth is quite completed, the number of eggs shed is below normal; thus a sow will on the average increase in litter size up to about the fourth litter, and remain at this high level for some long time, only decreasing in litter size again in extreme old age.

Similarly with lactation, the sow, which for its size gives much more milk than the cow, only breeds readily after the young are weaned. It is in the ewe, however, where the number of eggs ripened is the most important factor in fertility. Not only (as in the fowl) can the number of eggs shed be increased by breeding and selection for this quality, but also (as in the fowl) the method of feeding before the heat period plays a large part in increasing the number of eggs shed. Extra feeding, or "flushing," particularly on fresh green stuff such as mustard, rape, or a fresh pasture, just before and during tupping time, is the most important factor in ensuring a good crop of lambs. Since the number of eggs shed depends on the vigour and not on the fatness (which is deleterious) of the animal, the running out of the flock thinly on fresh ground, or the breaking up of a large flock into small lots, at tupping time will also raise the crop of lambs obtained. The rate of egg production in the fowl (see p. 641) varies greatly at different seasons of the year, owing to climatic conditions and to the amount of light. The effect of climate is also seen in the ewe (autumn) and mare (spring and summer), which have breeding seasons during which the eggs ripen, although in some breeds of sheep (Dorset Horn) the season is much extended. While in the cow breeding will occur all the year round, yet in spring and summer, when the cows are on grass, conception occurs more readily, for under wild conditions the cow breeds only at this time of year.

While in the fowl eggs ripen almost every day when conditions are favourable, in the mammals the time between the ripening of the eggs is spaced out so that these times (heat periods) recur about every three weeks in the mare, sow and cow. This is probably regulated by the formation and persistence of the corpus luteum in the vesicle from which the egg is shed (which does not occur in birds), the presence of this body preventing other eggs ripening, and it is not till the corpus luteum begins to atrophy (at the end of three weeks) that the animal comes on heat again. If the animal becomes pregnant the corpus luteum does not atrophy at the end of three weeks, but remains large and secretes into the blood substances necessary for the attachment and nourishment of the embryo, for when it is removed during pregnancy abortion follows. Occasionally, however, the corpus luteum remains large even though the animal is not pregnant, and such cows show no signs of heat for some time (two to three months or more). By inserting the hand into the rectum the corpus luteum can be squeezed out, and the cow will come on heat again within a few days (see Fig. 91). Another cause of sterility is due to the vesicle in which the egg is produced failing to rupture at the time of heat; the vesicles may then go on increasing in size and form large cysts, in which case the animals often show no further signs of heat, although not pregnant, or (there being no corpus luteum to prevent other vesicles ripening) may form a number of small cysts, in which case the animal will be continually coming on heat (nymphomania), showing

a high tail head and relaxed ligaments such as normally occur just before calving : such cysts may be cured by rupturing them by the hand through the rectum. The majority (90 per cent.) of heifers born twin to a bull are not fertile (Freemartins), because

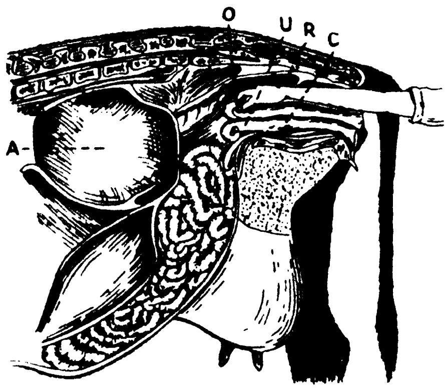
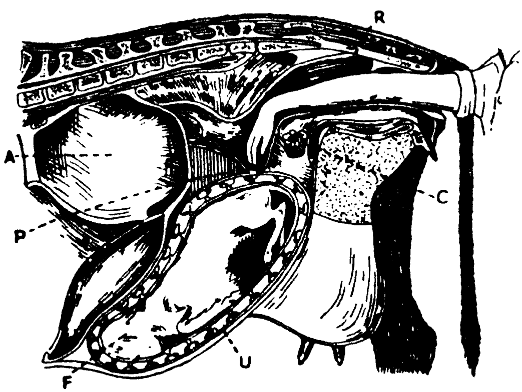


FIG. 91—RECTAL EXAMINATION OF THE REPRODUCTIVE ORGANS IN THE COW.

(*a*) *Non-pregnant*—with hand in rectum (R). After feeling the hard cervix (C) the division of the uterine horns (U) can be felt on the brim of the pelvis, and following these round, the ovaries (O) can easily be detected and the protruding corpus luteum squeezed out. A is the cavity of the rumen.



(*b*) *In late pregnancy*—with hand in rectum (R). The cervix (C) can be felt, but the uterus (U) and ovaries have dropped into the body cavity and only the lower end of the uterus and fœtus (F) and a few of the cotyledons (P) can be touched. A is the cavity of the rumen.

(From "Fertility and Animal Breeding," Bulletin No. 39. Ministry of Agriculture and Fisheries. By permission of Controller of H.M. Stationery Office.)

the development of the female organs has been inhibited by fusion with the blood system of the male twin ; the twin bull is, however, perfectly fertile, as also are both individuals of a pair of heifer twins.

The eggs, after being shed from the ovary, can only live for a few hours unless they are fertilized by sperm, so that mating usually takes place several hours before the eggs are shed, otherwise the eggs will not get fertilized. For example, the eggs laid by the fowl are not fertile until 28 hours or more after the hen has been mated. Similarly, although the sperm of the male can live for over a month in the male epididymis after it is formed, it does not live very long in the female passages, although the chances of living vary greatly in the different species. In the fowl most of the eggs will be fertile up to 7 days, and a few up to 15 or even 21 days after the cock has been removed from the pen; but in the larger farm animals the life of the sperm is probably very much shorter, and the chances of fertility are greatly decreased as the length of time (beyond that required for the sperm to ascend the tract)

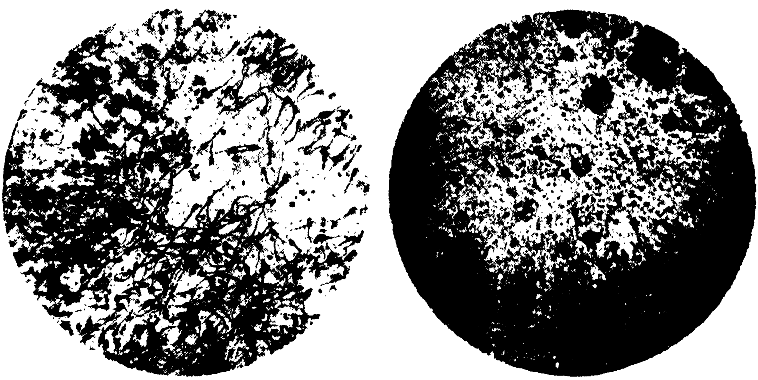


FIG. 92. APPEARANCE UNDER THE MICROSCOPE OF SEMEN FROM

(*a*) *Fertile Bull.* Swarming with actively motile spermatozoa.

(*b*) *Sterile Bull.* With only an occasional dead spermatozoon seen.

(From "Jour. Agr. Sci.," XI., 1921.)

between mating and the shedding of the egg is increased. In some of the farm animals the heat period is short (ewe, 3—51 hours, averaging 27 hours; cow, 6—30 hours, averaging 18 hours), so that no great length of time can usually elapse between mating and the shedding of the egg under normal conditions. In the mare, however, where the heat is long (3—15 days, average 6 days) there is a danger of mating too early in heat. The travelling stallion which serves mares once only at any time during the heat period averages only about 53 per cent. of foals, whereas the pony stallion which is run out with 6—8 mares and serves them at all times, will get 90 per cent. or more of foals. In such cases as the mare, where the sperm may have to live a long time in the female passages before the egg is shed, the chances of fertility are much more affected by the number of sperms that are produced by the male; thus

with travelling stallions some are regularly good "getters," producing up to 70 per cent. of foals each season, while others sometimes give results as low as 15—20 per cent. In all species the males may occasionally have periods, due to mismanagement, bad feeding, in-breeding, etc., when they are producing few or no sperms. Such animals may have all the desires and powers of mating, but it is easy to detect them by examining a sample of the semen under the microscope (see Fig. 92).

Under-feeding and over-using young males, and under-using or over-feeding old males, are, together with in-breeding, frequent causes of the failure to produce sufficient sperm. A common cause of sterility in the mare is the evacuation of the semen directly after service, thereby reducing the numbers of, and so the chances of survival, in the sperm. This can be prevented by keeping the mare moving after service, or use can be made of artificial insemination, the semen being caught in a basin and injected with a syringe into the uterus, from whence it cannot be extruded. Artificial insemination may also be made to extend the use of the best sires: in carrying out this practice, which is still in the experimental stages, the sperm has been found to live best outside the body when it is kept as far as possible away from air at temperatures of 50—60° F. Young have been produced by sperm kept up to seven days outside the body by this means in rabbits.

In many animals, and particularly the pig, a number of the embryos die off and are absorbed during the course of development, or are expelled in a mummified condition and eaten with the cleansings by the sow after birth (see Fig. 93). Thus in many adult sows which start with 15—20 young, only 4—7 live up to the time of birth. The cause has not yet been determined in pigs, but it is in all probability the same as that in rabbits, where it has been found to be a definite genetic character which can be selected and bred for: it is of the nascent type (see p. 410), *i.e.*, one which is likely to appear on in-breeding.

There are other causes which prevent the development of the young: heavy lactation after a sow is served before the young are weaned will cause the embryos to be absorbed. Feeding much frozen roots to ewes, and serious digestive troubles, are also liable to cause abortion, while a bacillus is the cause of a troublesome disease—Contagious Abortion—in cows (see p. 672). All these, however, differ from the above-mentioned genetic fœtal atrophy in that all the young are aborted or absorbed. Death of a few of the young only does not cause abortion, because the presence of some living young keeps the corpus luteum active, and so prevents abortion, whereas when this stimulus is absent the corpora lutea atrophy and birth or abortion takes place.

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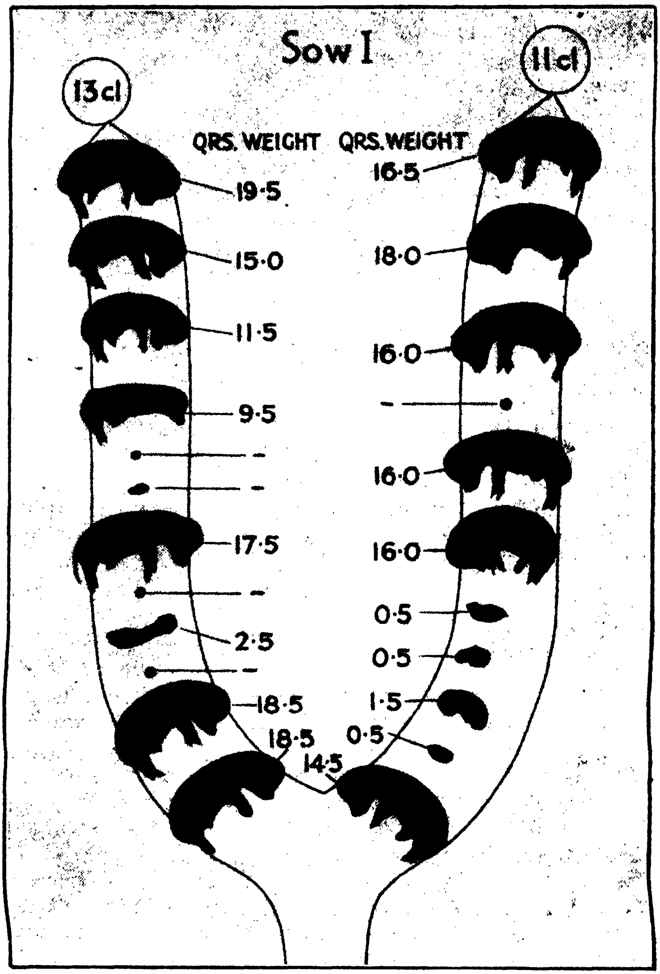


FIG. 93.—FŒTAL DEGENERATION IN A SOW KILLED ABOUT THE MIDDLE OF PREGNANCY.

Number of eggs shed at heat (as determined by the number of corpora lutea)	24
Number of normal fœtuses	12
Number of degenerate fœtuses	11
Eggs missing (probably not fertilized)	1

(From "Jour. Agr. Sci.," VI., 1914, Plate III.)

Milk Production.—The structure of the udder and the process of milk formation are briefly referred to on p. 522. The udder develops from the epidermal layer of the skin, which is thrown up into two ridges—the milk line—on each side of the abdomen; on this line at different points down-growing buds are produced, each of which eventually gives rise to a gland and teat. In the pig the line extends throughout the whole abdomen, but in the cow the buds, usually two on each side, develop only in the posterior portion; other smaller ones may often be found, usually behind or between the main ones, at different points on the line, but such "supernumerary glands" are of no value, and decrease rather than add to the function of the udder. This tendency is inherited, and can be selected against both in the bull and the cow, while in the individual they can be prevented by surgical removal of the supernumerary teats in early life. Nipple number is inherited in pigs, and the boar can increase or decrease the numbers in his offspring; these usually averaging a number intermediate between that of their parents. From the milk bud a sprout develops which grows down and then hollows out to form the milk cistern; from this some 12—16 secondary sprouts develop which by branching from the milk ducts, at the end of which later in life the milk secreting portion develops. This duct stage is reached at birth, when the development of the gland (apart from the fat associated with the udder) is much the same in both sexes.

The origin of the mammary glands from the skin is the cause of "seedy-cut," a defect which sometimes occurs in the belly portion of bacon (see Fig. 94). This only occurs in black pigs, the skin pigment being developed in the ducts of the glands as in the skin from which it arose. More is present in sows than in boars, and much of the development in sows is prevented by spaying, while in old sows which have produced a litter it is never seen, since the metabolism of the cells change to a milk secretion function during pregnancy and then lose their power of producing skin pigment.

The ducts of the udder develop further when the heifer becomes sexually mature, owing to a secretion from the corpus luteum circulating in the blood. The amount of such development bears no relation to the external size of the udder (which is due largely to fat deposits), for in the freemartin (a sterile heifer twin to a bull referred to above) the udder may appear quite large, but the amount of gland tissue, because of the lack of functioning ovaries and corpora lutea, is only equal to that of a calf at birth. When the heifer becomes pregnant very little change occurs in the udder until the twentieth week, when the alveoli or milk-producing parts of the gland begin to grow. Hitherto a thin watery secretion can be drawn from the teat, but now this secretion changes to a thick, honey-like secretion rich in globulin; it is this secretion mixed with the milk which is formed later which gives rise to the "colostrum," or first milk, which coagulates on boiling. Globulin is associated with the anti-bodies of diseases to which the cow has been subjected,

so that it is important that the calf should receive the colostrum [illegible] after birth. In cows which are already in milk, the yield begins

FIG. 94.—" SEEDY CUT " : THE MAMMARY GLANDS OF THE PIG CONTAINING BLACK PIGMENT ORIGINATING FROM THE SKIN.

The occurrence of this detracts from the value of the pig for bacon, as the area containing it has to be cut away before the side is cured. The bacon is perfectly good, but is objected to by the consumer.

(From Messrs. C. & T. Harris, Calne, Wilts.)

to decline sharply at this stage (twentieth week of pregnancy), for the gland cannot both function to secrete milk and also grow to fullest extent at the same time. It is essential that full growth of

the udder should take place if a high yield is to be made in the next lactation, so that cows should be dried off for 40—60 days before calving again ; in this time almost complete growth can be made, but a shorter dry time usually curtails it, and so the subsequent yield falls considerably (see p. 620, " Corrections for Dry Period ").

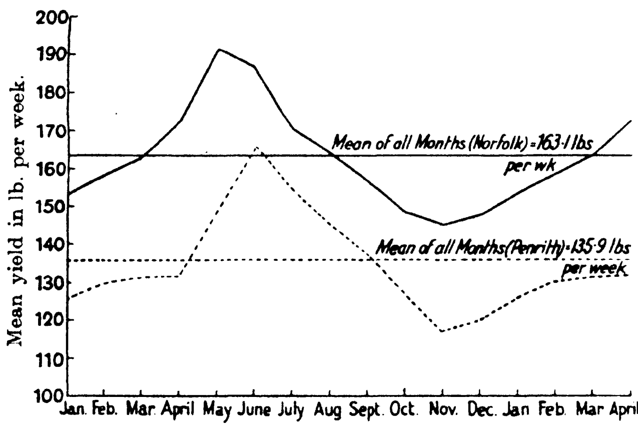
The growth of the gland can also be assisted by feeding the cow well before calving—the so-called " steaming-up " process. Such feeding should consist of a high protein ration such as is suitable for milk production, so that a hard physical condition and growth are promoted rather than fattening. At the time of calving, however, a laxative diet should be fed, as this assists cleansing, and also acts as a preventive of milk fever. Although dependent on the time of year a cow calves (due to feeding conditions), the milk yield usually rises under optimum feeding conditions to a maximum about six weeks after calving. During this time, in order to obtain the maximum output, a cow should be fed with an allowance of concentrated food above that sufficient for the yield she is actually giving. The method of feeding affects the rate of milk secretion considerably. In general, the proportion of protein should be high, the bulk (fibre) of the ration limited, and the diet made slightly laxative, so that the rate of digestion may be increased ; but when large quantities of meals are being fed care should be taken to see that the mixture is " light " (for example, bran and flaked maize as compared with maize meal or bean meal), *i.e.*, will not paste when mixed with water, or otherwise digestive troubles will occur. Lightness, without unduly increasing the bulk, may be given to a ration by adding sugar-beet pulp, in which the fibre or cellulose is easily digestible.

The rate of milk secretion is also greatly affected by pressure : the function of the milk cistern (see p. 613) is to relieve pressure on the gland and form a reservoir from which the calf can draw it off periodically. After milking, when the pressure within the udder is low, secretion occurs at a fast rate, but as milk accumulates in the udder the internal pressure rises, and the rate of secretion is slowed down. Thus when a cow is milked every four hours, and milk is being secreted at the rate of 1·13 lb. per hour, the same cow will, if it is milked at 12-hour intervals, only secrete milk at the rate of 0·7 lb. per hour. The yield in each successive hour after milking is approximately 90 per cent. of the previous hour's yield ; this fact forms the basis for the practice of equalizing the intervals between milkings as far as possible, and is the reason why three times a day milking will produce some 12—15 per cent. more milk than twice a day milking.

Frequency of milking is especially important in high producing cows if their high yields are to be maintained, for nothing inhibits the production of milk more than leaving milk in the udder : for this reason milking should always be done thoroughly. The cure for milk fever effected by pumping up the udder with air owes its efficiency to the fact that the pressure so set up slows down the

rate of milk secretion. All the milk which is obtained from the udder at any milking is already present in the udder when milking begins; it was formerly thought that part at any rate, was produced by the stimulus of milking, particularly so as some cows have the power of holding up their milk. This, however, is due to a nervous reflex by which the milk is prevented from passing through the fine ducts, and occurs when the cow has been frightened or disturbed; milking should therefore be done as quietly as possible, and if any trouble occurs the cow's back may be scratched to put her at her ease again.

Milk records have been a means of improving the yields of milk by both breeding, feeding and management. A study of these under different commercial conditions of management in different districts soon shows up defects and suggests means of improvement. Under commercial conditions there is a great seasonal difference in the yield of milk given by cows at different times of the year. For example, in a herd where an equal number of cows calved in each month of the year, the output would be as follows :—



Mean yield during different months of the year.
Norfolk ————
Penri.h - - - - - - - -

FIG. 95.—THE SEASONAL VARIATION IN THE RATE OF MILK SECRETION.

The curves show the mean weekly yields per cow during the different months of the year in a herd where an equal number of cows calve down each month, *i.e.*, where other factors than the seasonal effect are eliminated.

(From "Jour. Agric. Science," XVII., 1927.)

Differences between the two districts show up the effects of agricultural practice therein. In the winter months, during which the feeding is much the same, the yield remains fairly uniform, but when the cows are turned out to grass in the spring the yield goes up quickly (owing to the non-bulky and high protein content of the young grass) while in July (when the grass gets old and fibrous) the yields begin to fall off rapidly. Thus throughout the country

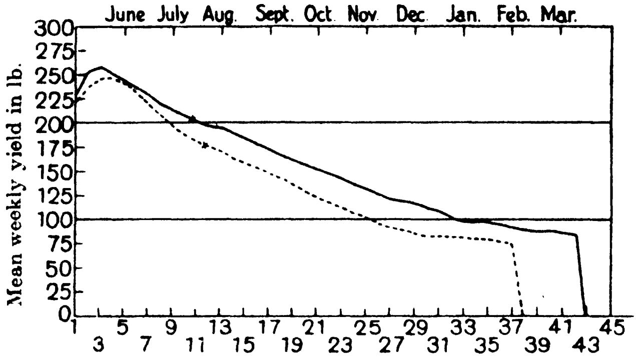
there is usually a surplus of milk in May and June which must find some other outlet than consumption as liquid milk ; this surplus can be partially avoided by calving a higher proportion of cows during the late autumn months (as is done in the arable districts supplying the winter milk to towns), while the production of cream, butter and cheese, combined with pig-feeding and veal production, can be used to take off any remaining surplus production. On the other hand, in the grassland districts of the west, advantage is taken of the relatively inexpensively produced young grass, which has a high value for milk production, to produce cheap milk (for cheese and condensing) by calving almost all the cows in the early spring months, so that their maximum production occurs at a time when this food is available.

Owing largely to the seasonal variations in feeding the total lactation yields of cows will vary with the time of year they calve, cows calving in the autumn and winter months giving a higher total lactation yield than those calving in May—August. How this is brought about can be seen by studying the average shapes of the following "lactation curves" (Fig. 96) of cows calving in different months of the year.

The May calver gives a higher yield at first (maximum yield) owing to the effect of the young grass on which she is being fed, but her yield quickly falls off as the grass gets old and fibrous, and it continues to fall, so that she is on the average dry in 38 weeks. On the other hand, although the October calver does not yield so much at first because she comes in on winter rations, she milks steadily on these, and just as she is beginning to fall off she is turned out to grass in the spring, which causes her yield to rise, so that she does not become dry on the average until the forty-fourth week. The better cows are fed and managed, however, the less difference will there be between two such curves in a herd ; those given represent actual averages of Milk Recording Societies.

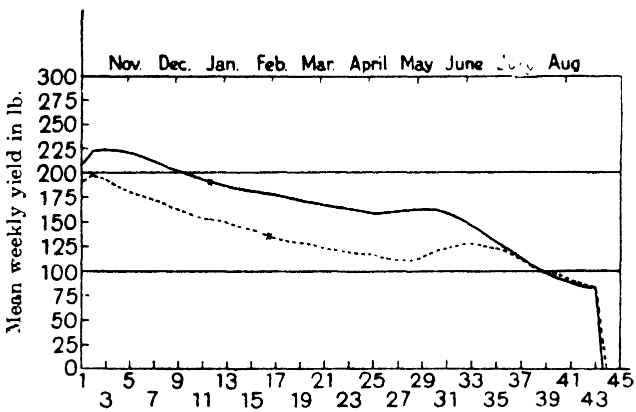
The fall of milk yield during the lactation period is due to the gradual wearing out or senility of the gland. Just as the animal as a whole has a period of growth, of adult vigour, and of senile decay, so the tissues of the mammary glands undergo such changes and have to be rejuvenated periodically in the life of the animal. They are presumably rejuvenated by internal secretions produced during pregnancy (see p. 614), and since during this process the yield of milk is inhibited, there is an optimum length of time between calving and the next service, and so the next lactation. It has been found that with cows averaging about 8,000 lb. of milk in the lactation, that calving at yearly intervals gives the maximum output, for if calving is more frequent the total life production is depressed by the effect of short dry periods, preventing full subsequent lactation, and if calving is less frequent then so much time is spent on the low end of the lactation period that the output is again reduced. Where higher yielding cows are used, however, the intervals between calvings may, with advantage, be prolonged to

15 months. Heifers, after their first calf, are best given a rather longer rest before their second as, not only is their lactation curve



(*a*) May Calvers.

Norfolk ——— No. of lactations = 232 ; Mean total lactation yield = 6,649 lb.
Penrith - - - - - - No. of lactations = 122 ; Mean total lactation yield = 5,343 lb.



Weeks after calving.

(*b*) October Calvers.

Norfolk ——— No. of lactations = 415 ; Mean total lactation yield = 7,099 lb.
Penrith - - - - - - No. of lactations = 106 ; Mean total lactation yield = 5,677 lb.

FIG. 96.—THE LACTATION CURVE, SHOWING THE CHANGES IN SHAPE DUE TO DIFFERENCES IN SEASONAL CONDITIONS.

(*a*) *From cows calving in May.* Note the high initial yield and sharp fall during the autumn months.

(*b*) *From cows calving in October.* Note the lower initial yield, but slow decline during the period of winter feed, and the rise that occurs in May and June.

(From " Jour. Agri. Sci.," XVII., 1927.)

unusually prolonged as compared with older cows, so that the development of the udder suffers from a short dry period, but their

body is usually still growing, and a slightly longer rest will give a better developed cow.

The yield of milk given by a cow rises on the average with successive lactations up to the sixth, and then begins to decline at much the same rate. This fact is made use of by some breeders, who keep young cows up to the fourth or fifth calf while they are appreciating in value, and sell them at their maximum to town dairies when they are milked out and fattened before they begin to depreciate. In advanced registers of herd books the yields to qualify for entry at the different ages are based on such average figures for increase with age. For example, the British Friesian Society have a scale ranging from 8,000 lb. at 2½ years old or under to 13,000 lb. at 5 years old and over.

Breeds vary considerably according to the average amount of milk and percentage of butter fat they give, but there are also within each breed variations as large as the differences between breeds. The following average figures for the yields and fat percentages of the different breeds at the London Dairy Show will give an idea of the comparative maximum yields of the different breeds. These will give an indication of, although they are not absolutely related to, the total yield given in the lactation, for some breeds and individuals which have a high maximum yield tend to dry off quickly, while other breeds and individuals in which the maximum yield is comparatively low are very persistent in lactation. The Lincoln Red and the Red Poll are examples of these two types respectively.

TABLE I.

PRODUCTION OF FIVE-YEAR-OLD COWS OF DIFFERENT BREEDS AT 40 DAYS AFTER CALVING. (*London Dairy Show*, 1876-1925.)

Breed.	Daily Yield. Lb.	Fat percentage.	Lbs. of milk required to make 1 lb. of butter (1919 1928).	(1928). Fat by analysis.	Butter churned.
				lb.	lb.
Dairy Shorthorns	49·2	3·81	27·90	1·52	1·29
Jersey	34·6	5·00	18·69	2·04	2·18
Guernsey	36·1	4·71	21·60	1·80	1·87
British Friesian ...	57·6	3·68	32·01	2·10	1·88
Red Poll	45·9	3·69	28·54	2·13	1·83
Ayrshire	50·2	4·02	25·08	2·28	2·24
Lincoln Red ...	48·0	3·67	27·35	2·51	2·13
Kerry	36·6	4·23	26·33	1·38	1·14

Since the lactation yield of a cow varies with environmental conditions, these should be taken into account when comparing the value of different cows in the herd for purposes of selection in breeding. The following table shows what corrections should be made to standardize a lactation record for these environmental conditions :—

TABLE II.—CORRECTIONS FOR STANDARDIZING A LACTATION RECORD.

MONTH OF CALVING. (Standard—Mean of all Months, *i.e.*, approximately March and Sept.) Month of Calving.	
Jan. ...	− ·9 %
Feb. ...	− 2·8 %
Mar. ...	− ·2 %
April ...	− 2·2 %
May ...	+ 3·4 %
June ...	+ 7·0 %
July ...	+ 5·0 %
Aug. ...	+ 3·0 %
Sept. ...	+ ·5 %
Oct. ...	− 4·7 %
Nov. ...	− 2·6 %
Dec. ...	− 3·8 %

SERVICE (Standard 85 days). Length of Service Period.	1st Calvers.	Others.
0–19 Days ...	+ 28·2 % ...	+ 33·9 %
20–39 ,, ...	+ 18·4 % ...	+ 21·3 %
40–59 ,, ...	+ 10·6 % ...	+ 11·9 %
60–79 ,, ...	+ 4·2 % ...	+ 4·6 %
80–99 ,, ...	− 1·1 % ...	− 1·1 %
100–119 ,, ...	− 5·5 % ...	− 5·9 %
120–139 ,, ...	− 9·2 % ...	− 9·7 %
140–159 ,, ...	− 12·4 % ...	− 12·9 %
160–179 ,, ...	− 15·2 % ...	− 15·5 %
180–199 ,, ...	− 17·6 % ...	− 17·8 %
200–219 ,, ...	− 19·7 % ...	− 19·7 %
220–239 ,, ...	− 21·5 % ...	− 21·4 %
240–259 ,, ...	− 23·1 % ...	− 22·8 %
260–279 ,, ...	− 24·5 % ...	− 24·1 %
280–299 ,, ...	− 25·8 % ...	− 25·1 %
300–319 ,, ...	− 27·0 % ...	− 26·1 %
320–339 ,, ...	− 28·0 % ...	− 26·9 %
340–359 ,, ...	− 28·9 % ...	− 27·6 %
360–379 ,, ...	− 29·8 % ...	− 28·3 %
380–399 ,, ...	− 30·5 % ...	− 28·8 %
400–419 ,, ...	− 31·2 % ...	29·3 %
420–439 ,, ...	− 31·8 % ...	− 29·8 %
440–459 ,, ...	− 32·4 % ...	− 30·2 %
460–479 ,, ...	− 32·9 % ...	− 30·5 %
480–499 ,, ...	− 33·3 % ...	30·8 %

AGE (Standard 6th Lactation). Lactation.	
1st ...	+ 30·6 %
2nd ...	+ 18·0 %
3rd ...	+ 9·3 %
4th ...	+ 3·7 %
5th ...	+ ·7 %
6th ...	—
7th ...	+ 1·4 %
8th ...	+ 4·8 %
9th ...	+ 10·4 %
10th ...	+ 18·5 %
11th ...	+ 29·4 %
12th ...	+ 43·7 %

DRY PERIOD (Standard 40 days). Length of Dry Period.	2nd Calvers.	Others.
0–9 Days ...	+ 25·1 % ...	+ 14.0 %
10–19 ,, ...	+ 15·2 % ...	+ 8·8 %
20–29 ,, ...	+ 8·0 % ...	+ 4·7 %
30–39 ,, ...	+ 2·8 % ...	+ 1·5 %
40–49 ,, ...	− 1·3 % ...	− 1·2 %
50–59 ,, ...	− 4·4 % ...	− 3·3 %
60–69 ,, ...	− 6·4 % ...	− 5·0 %
70–79 ,, ...	− 8·8 % ...	− 6·5 %
80–89 ,, ...	− 10·4 % ...	− 7·6 %
90–99 ,, ...	− 11·7 % ...	− 8·6 %
100–109 ,, ...	− 12·7 % ...	− 9·4 %
110–119 ,, ...	− 13·5 % ...	− 10·1 %
120 and over ...	− 15·0 % ...	− 12·0 %

EXAMPLE.—To compare two cows with the following lactation records :—

	Calving her	In	After being Dry	Being Served 108 days after calving	Giving a total yield in the lactation of
Cow A ...	5th Calf	Oct.	73 days	calving	12,000 lb.
Cow B ...	2nd ,,	June	14 ,,	28 ,,	8,000 lb.

Corrections are—	*A*.	*B*.
For month of Calving...	− 4·7 %	+ 7·0%
For length of S.P.	− 5·9 %	+ 21·3%
For age	+ 0·7 %	+ 18·0 %
For length of D.P.	− 6·5 %	+ 15·2 %
Total	− 16·4 %	+ 61·5 %

i.e., Corrected Yields are—

$$A = 12{,}000 - \frac{16 \cdot 4}{100} \times 12{,}000 = 10{,}032 \text{ lbs.}$$

$$B = 8{,}000 + \frac{61 \cdot 5}{100} \times 8{,}000 = 12{,}920 \text{ lbs.}$$

The odds are about 13 to 2 that *B* is a better cow than *A*.

While such methods allow of a fairly accurate selection of cows, difficulties are met with in the selection of the bull, since no measure of his actual production is possible. By recording the average corrected yields of his daughters, however, his breeding value for milk production can be measured. Breeding from these proved bulls is the most certain method of improving milk yields, but the time which must elapse before the bulls can be tested makes them difficult to obtain. By testing bulls regularly, however, both sides of the pedigree for milk production can be filled in, and the methods of breeding for milk production will probably develop along these lines.

The milks of different species of animals can be classified into two types, according to the nature of the chief protein which they contain. The albumin, or rather "globulin," milks are those in which the proportion of these proteins is high ; in these it is not easy to produce a curd or make cheese, as these substances protect what casein there is present from the action of rennet. They are probably of a lower evolutionary type, and are much like the colostrum of the cow in their properties ; human and mare's milk is of this type. The other type, "casein milks," in which casein is the chief protein form a curd with rennet and can be used for cheese-making ; the milks of the cow, ewe and goat are of this type, although during the inception of the secretory process they pass through the globulin stage as may be observed in the colostrum. As pointed out above, colostrum is formed during the growth of the gland, and so if the cow is milked up to the time of calving, more milk and not colostrum is produced directly after calving.

Of the constituents of cow's milk, the lactose and casein are the most constant in the proportions present ; there is some variation in these, however, and milk may occasionally fall below the official standard for solids-not-fat (8·50 per cent.). Lactose is not found elsewhere in the body, and is undoubtedly formed in the mammary gland from the blood. Of the two main theories of milk secretion : (1) that with the formation of lactose the osmotic pressure so set up in the cell draws in water and washes the proteins out to form milk ; and (2) that a glycoprotein substance is built up in the cell which by the action of calcium is broken down into casein and lactose—not sufficient evidence is yet available to form complete proof of either. The older theory that milk was formed by the tops of the mammary cells breaking down has, however, been shown to be erroneous. Fat, which is the most variable constituent, is formed as minute globules in the cells, and is extruded or washed out of the cell by the flow of fluids. Since the fat is commercially the most important constituent, some of the causes for variation in its percentage may be described.

It has been noted above that pressure on the udder slows down the rate of milk secretion. This effect is much more marked on the fat than on the other constituents, so that where cows are milked at unequal intervals of time, the percentage fat in the milk

obtained in the evening after the short interval is usually much higher than that obtained in the morning's milk after the long interval. In cases where the morning's milk is on the border line of the official standard (3 per cent.), but the evening's milk well above standard, the danger of deficiency can be avoided by more nearly equalizing the intervals between milkings. As the surface tension of the fat globules is higher than that of the milk fluids the fat passes down the small milk ducts more slowly than the other constituents, and so the milk first drawn is usually very low in fat (1·5 per cent.), and the percentage rises gradually up to the end of milking (often 10 per cent. fat). The strippings should therefore be mixed equally with the other milk, and not all put into the same churn, if an even sample is to be obtained. For this reason cows should be milked quickly, so that the flow down the small milk ducts is swift, and the fat globules more completely removed.

The rate of secretion in the solids-not-fat and the fluids of milk is more easily influenced than is the rate of the formation and secretion of fat, so that as a rule those conditions which cause a quick rate of milk secretion tend to reduce the percentage of fat in it. Thus during the course of lactation the fat percentage gradually falls until the maximum yield is reached, and then rises again to the end of the lactation as the yield falls. Bad feeding, or digestive troubles which decrease the yield, generally raise the fat percentage, although subsequent good feeding and increase in yield will cause it to fall again below normal. The increase in yield of milk in the cow with age up to the sixth lactation is not, however, associated with any marked decrease in the fat percentage of the milk, for such an increase in yield is not so much due to increased rate of secretion as it is to increase in the area of the gland. Breed differences in yield may be due to both rate of secretion and to area of gland, so that in many cases increase in yield due to breeding is associated with a lower fat content, while in other cases it is not, thus not all cows of high-yielding breeds necessarily give milk low in fat percentage, although in general this occurs. While feeding has little, if any, effect on the fat percentage of the milk, except in so far as it increases or decreases the total yield of milk, yet certain foods, such as palm nut and coco-nut cakes, especially when rich in fat, are said to prevent the fall in fat percentage when the yield is increased by feeding; possibly this may be due to their fats being very similar to butter fat in composition.

The average size of the fat globule is an important factor in determining the use of the milk. In milk such as that of the Jersey and Guernsey, with large fat globules, the cream rises easily, and the ratio of butter to milk obtained (even with equal fat percentages —see Table I) is much higher than with breeds producing milk with small fat globules, such as the Ayrshire and Friesian. The milk of the latter, however, is more useful for condensing and cheese-making, as the fat is more evenly distributed throughout the sample.

The rising of cream on milk, and the formation of a thick cream-line (which is important when selling bottled milk), is not only assisted by the presence of large fat globules, but it is mainly induced by an agglutination (similar to bacterial agglutination) of the globules caused by the presence of small quantities of globulin in the milk. Pasteurization of milk at high temperatures coagulates the globulin and prevents the formation of a good cream-line, which can, however, be regained by the addition of small quantities of this substance from skim-milk or colostrum.

The colour of butter, and likewise of cream and milk, is due to a pigment (carotin) which is produced from the green colouring matter of plants. Feeding on greenstuff will give a dark yellow coloured butter, while feeding on white-fleshed mangolds or much concentrated food will give pale milk and butter. While certain breeds, such as the Jersey and Guernsey, develop a high degree of colour when fed on the appropriate foods, other breeds are not capable of producing so rich a colour. With body fat, yellow colour behaves as a Mendelian recessive to white in inheritance. The softness or firmness of the butter fat, like that of body fat, may be influenced to a certain extent by feeding : cotton cake tends to give a hard white fat, while linseed cake gives a soft yellow fat. In general, when the animal has to synthesize its fat from carbohydrates in the food, the fat will tend to be hard, while if fat is fed in the food it generally has a softening effect on body and butter fat. Conditions which cause rapid fermentation in the rumen, such as turning the cows out on young grass or clover, or the addition of sugars to the ration, cause the formation of the lower fatty acids such as butyric in the alimentary canal, and so frequently result in soft butter.

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Growth and Meat Production.—When a cell increases in size its volume enlarges at a greater rate than its surface, and so the metabolism, or exchange of energy, which can only occur at the surface, is inhibited and further growth becomes impossible. It therefore divides into two, and each daughter cell repeats the process. As the organism increases in size sets of cells become specialized and take over different functions : once the cells have become specialized for a particular purpose they lose their power of division, and so growth of the animal as a whole becomes slowed down. Thus growth consists essentially of two things, increase in size and differentiation of tissues ; or, in other words, as an animal grows up it not only increases in size, but it also changes in its

shape or conformation. The former controls the quantity of meat the farmer has to sell, while the latter forms the basis of quality. The differences in size between different breeds at the same age is mainly due to differences in the number of cells and only very slightly to differences in the size of the cells. In the specialized cells like those of muscle, the growth up to about the time of birth consists mainly of increase in cell number, whereas most of the growth occurring after this time consists of increase in cell size, associated with which there is also increasing toughness of the tissues.

There are many ways of measuring the rate of growth : the proportional increase in size, *i.e.*, the percentage gain in a given time is the usual scientific method, and from this equations may be worked out which will express the average rate of growth occurring at different ages. On the basis of this work it has been considered by some that the process of growth is like a chemical autocatalytic reaction, and slows down as the accumulation of the products occurs. For agricultural purposes, however, the best measure is the actual weight gained in a period of time. This actual growth rate gradually increases with the increasing size of the animal until a maximum point is reached, when the limits imposed by the increasing size (and so difficulties of nutrition) of the body, and differentiation of its tissues, cause a gradual decline in rate of increase, which in extreme old age and senile decay changes to an actual decrease in weight. The age at which the maximum daily rate of increase is reached varies in the different species, and occurs earlier when the nutritive conditions are better. Since with increasing size of the animal an increasing amount of food is required daily for maintenance, the sooner the animal can be fattened off after the period of maximum growth rate, the more economically will the meat be produced from the food consumed.

Quantity in meat production or growth in live weight depends on many factors included in feeding and management, in addition to those of breed. Breed differences may be large, as the following averages for fat animals exhibited at Smithfield (1893—1913) show:—

Cattle (Steers).	Lb. at 22 months.
South Devon	1,512
Shorthorn ...	1,410
Sussex ...	1,389
Hereford ...	1,384
Welsh ...	1,371
Aber.-Angus	1,362
Red Poll ...	1,276
Galloway ...	1,219
Devon ...	1,218
Dexter ...	820

Sheep (Wethers).	Lb. at 9 months old.
Lincoln ...	198
South Devon	196
Cotswold ...	188
Suffolk ...	188
Hampshire ...	177
Oxford ...	175
Leicester ...	172
Kent ...	170
Cheviot ...	161
Dorset Horn...	158
Shropshire ...	158
Blackface ...	148
Southdown ...	137

Pigs.	Lb. at 9 months old.
Large White	390
Large Black ...	371
Berkshire ...	337
Tamworth ...	334
Middle White	325

The actual live weight of the breed, however, bears little relation to its value for meat purposes (apart from weight of produce), for the latter is determined mainly by the conformation or proportions of the body rather than by actual size. In cattle, and particularly in sheep, which under commercial conditions are dependent for the bulk of their food supply on grazing or the crops grown locally, the nature of the climate and soil very largely determines the optimum size of the animal. Where grazing is sparse a large animal will not be able to gather sufficient food in excess of that required for maintenance to give high production in the form of rapid growth and fattening, and will therefore be deficient in conformation or quality of meat (see below). A small animal, on the other hand, will have a larger surplus for production, because of its lower maintenance requirements, and so will be able to maintain good conformation. In districts of very poor grazing, sheep will be more profitable than cattle for this reason. Many of the problems in the feeding and management of meat animals hinge on this question of being able to supply a high surplus of nutrition for production above that required for maintenance. The ruminant digestion of foods containing much fibre is a comparatively slow process, and does not furnish a high absorption rate of nutrients into the blood per unit of time, although it extracts more from these classes of foodstuffs than the simple stomach of the non-ruminant. The method of feeding for meat, therefore, should be the same in principle as that already outlined for milk (see p. 538), where baby beef or early lamb is concerned, but with the addition that with older animals, which are merely being fattened after having completed their growth, a larger proportion of carbohydrates should be used. Roots are particularly useful for this purpose, as they are essentially a concentrated food plus water, and the fibre which they contain is easily digested.

In former times, when fresh grass in the summer and hay in the winter were almost the only available feeding-stuffs, cattle could not be fattened off until four or five years old. The hay in the winter was only sufficient for maintenance ; the grass in the summer would provide for maintenance and growth, but not for fattening ; and so it was only when growth was completed and the demands for this purpose lessened, that surplus nutrition became available for fattening. The introduction of roots into cultivation by providing a form of watered concentrate feed for winter feeding, and the increasing availability of the concentrated industrial by-products, such as linseed and cotton cakes, enabled the farmer to increase the surplus of nutrition above that required for maintenance and growth all the year round; and so reduced the age at which cattle and sheep could be fattened and killed. Saleable beef can now be produced at 15 months old as compared with the 4 years it took to produce in 1830.

In areas where poor pasturage or much bulky fibrous food is produced relatively cheaply, cattle are frequently merely reared and

grown, being sent to other districts—for instance, from Wales to Midland grassland districts, and Ireland to the Norfolk root area —to fatten at about the age of two years. Although this process involves a greater total consumption of food per unit of meat produced, it will not generally be profitable to do otherwise until these districts find some means of producing concentrated feeds on the farms. The method of keeping cattle in growing condition only (stores) and then fattening later is not only uneconomical in the total consumption of food per unit of meat produced, but it also produces a carcass and conformation less suited to butchers' requirements (see p. 636). Just as the store period leads to a greater total consumption of food to produce a given weight of meat, owing to the longer time over which the maintenance food has to be supplied, so, as a general rule, those animals which reach a certain weight in the least time do so with the smallest consumption of food per pound of weight gained. Thus, for practical purposes, such as in the Pig Recording Societies recently started, it is sufficient to record the weight for age as the basis of real economic gain (*i.e.*, food consumed) without the trouble of recording the food intake. In the growth of young animals the amount of the milk supply is an important factor; for example, in Suffolk sheep the average weights of singles, twins and triplets are as follows:—

	Actual Weights. Lb.				Relative Weights. Twins = 100.			
	1 week.	15 weeks.	25 weeks.	66 weeks.	1 week.	15 weeks.	25 weeks.	66 weeks.
Singles	15·9	88·5	110·1	162·3	137	125	117	109
Twins	12·0	69·5	95·1	148·8	100	100	100	100
Triplets ...	10·0	66·0	91·4	143·0	81	94	94	96
Twins reared as singles	12·4	75·8	102·1	—	102	119	110	—

The yield of milk produced by the dam has, in both sheep and pigs, a great influence on early growth. Not only are animals which obtain in this way a good start in life more able to resist the attacks of disease, but such differences in size may persist for a long time, although they gradually tend to become less as the animal becomes older. Unless twins and singles are marked and drafted into different pens at the time of selection, there will always be a tendency to pick out most of the singles for breeding purposes, and so reduce the fertility of the strain. If the best of the twins (both rams and ewes) are picked out and bred from, selection will be made for both fertility and milk production in the ewe, as well as meat qualities in the lambs.

Animals retarded in their growth rate for a short time by under-nutrition will, when put on a high plane of feeding, grow for some time at a faster rate per unit of time than those well fed all the time, although their ultimate size will be less. Thus, in selecting animals for feeding, it is better to buy them from poorer districts than to transfer animals for this purpose from better pastures to poorer ones. In addition to the general energy nutritional requirements of the animal, there exist special substances which control the growth rate. The effect of vitamins is well known, although liability to deficiency in this respect varies greatly in the different species, and is comparatively small in most well-managed farm animals. Body growth is also regulated by the glands of internal secretion, particularly the anterior pituitary and thyroid, but at present the application of these to increase normal growth is still in the experimental stages.

The quality of meat is largely determined by the degree to which the proportions of the animal change as it grows up. Unlike wheat, where the quality, and so the price, of the imported product is higher than that produced in this country, the high-quality meat produced in this country commands a better price than the imported, so that the farmer, in order to avoid competition with the imported product, should aim at improved quality in production, even if it has to be produced at some expense of quantity. Quality is largely dependent upon early maturity, or the rapid attainment of adult proportions, and in general this can be brought about more readily in the smaller animal than in the larger one. The combination of the two—quality and quantity—for commercial purposes may, however, be brought about by crossing. Males from the early-maturing, high quality types, when crossed with the females of the larger and later-maturing breeds, give offspring which inherit both characters. The value of the Southdown ram, the Berkshire or Middle White boar, and the Aberdeen-Angus bull for crossing with the later-maturing breeds is well known.

The two functions of growth—increase of size and change of conformation—are partially independent of one another, and this is especially marked when different breeds are compared. The main object in breeding for quality in meat is to speed up the rate at which the body changes its proportions, and to make these changes occur more quickly in relation to the weight increase; in this way early maturity is produced. It is these rapid changes in the proportions of the body which constitute the real basis of early maturity and quality in meat animals, and not, as has frequently been supposed, the rapid increase of live weight alone. The British early-maturing meat type of animal has been gradually evolved on this basis, mainly through the organized efforts of the Smithfield Club. At the annual show all breeds and crosses compete against one another for the supreme honours, so that the commercial qualities for meat production are here placed before the fancy points of the breed.

A general idea of the changes in the proportions of the body in the pig as it grows up are shown in Fig. 97.

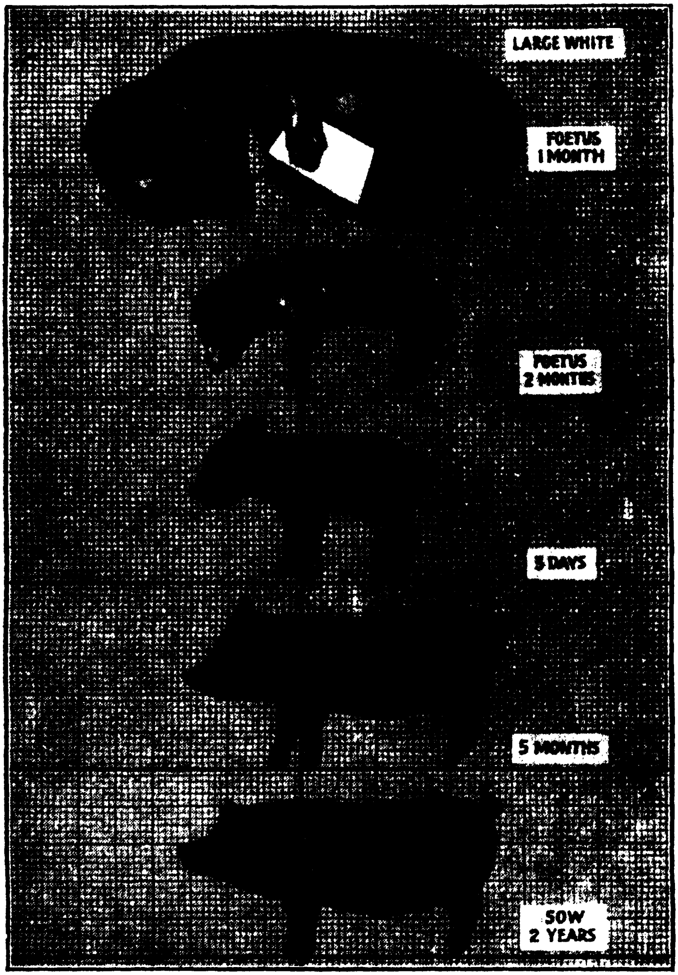

FIG. 97.—THE CHANGES IN THE PROPORTIONS OF THE BODY IN THE LARGE WHITE PIG DURING THE COURSE OF ITS LIFE.

In order to show proportions as distinct from size, the photographs are all reproduced to the same height at the shoulder : the proportions of each part can be estimated by the number of squares it occupies.

(From " Pig Breeders' Annual," 1927-28.)

In order to show the changes in the proportions as distinct from size, all the animals have been reduced to the same height at the

shoulder : this is a convenient measurement on which to base a visual estimation of proportions in the living animal. Since the height at the shoulders attains its maximum proportions about the time of birth, it also forms a good measure by which to judge the animal after birth, for all the changes take place in one direction only. Before about the time of birth, however, the changes in relation to this measurement are in the other direction, because the limbs have not yet attained their maximum proportions. In order to obtain a series in which all the changes were in one direction only, the size of the cranium would have been a better standard to take, for this part attains its maximum proportions at a very early stage of fœtal development. It will be seen that as the animal grows up it improves in quality : for example, the relative proportions of the head and legs are reduced. Were these animals of the same age, the one at five months old would be said to have a "coarse" (or relatively large) head, while that at two years old would have a "fine" (or proportionately small) head of good quality. Again, considering the ham, at birth the bone is coarse and the muscles are deficient, but at five months, and still more at two years old, the bone becomes relatively finer, the muscles develop, and the buttock fills out ; these are just those differences which make a bad quality or good quality ham. That is, in the improvement of the animal for meat, the one that goes through those age changes in proportions most rapidly, and approaches mature proportions of the body at lowest weight, would be the best, and would be selected for breeding purposes : this forms the main basis of judging animals for meat purposes.

The wild and unimproved types of animals also change in their proportions as they grow up, but not to such an extent as do the improved breeds. Breed improvement for meat has been produced by pushing the natural changes in the proportions of the animal a stage further in development, so that the proportions attained in the adult wild type are passed through in the improved breeds early in life. The male usually attains a higher degree of development than the female.

Fig. 98 shows that in the wild sheep (Mouflon) the proportions of the legs decrease and the body lengthens and becomes deeper as the animal develops ; the improved Suffolk breed, however, has been pushed still further in development, so that the proportions of the Suffolk lamb at birth are but little behind those of the adult Mouflon ewe (*i.e.*, the proportions are attained at much earlier age), while in adult life the relative lengths of the back and loin (the most valuable parts commercially) are very much increased.

The changes in the proportions of the body are brought about by the different parts of the body growing at different rates. Just as the actual live weight increase of an animal per unit of time rises to a maximum and then falls again, so each organ and tissue of the body has a time of actual maximum growth rate which varies for each organ or part of the body. Fig. 99 shows how the

relative weights of the bone and muscle in the leg of mutton change as the animal grows up.

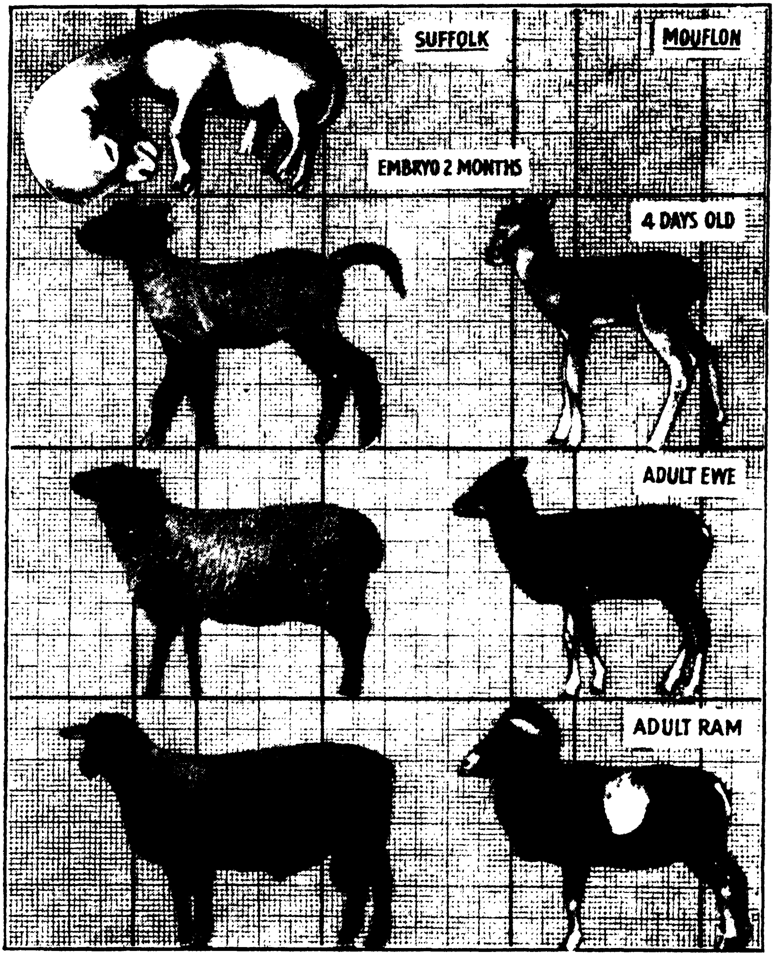

FIG. 98.—THE DIFFERENCES IN THE PROPORTIONAL CHANGES WITH AGE BETWEEN THE IMPROVED SUFFOLK AND THE WILD MOUFLON SHEEP.

The outline of the body is shown as a proportion of the height at the shoulders in each case.

Note the decrease in the proportions of the head throughout, and the legs from birth onwards. The length and depth of body in relation to the height at withers also increases greatly with age, and increases both more and earlier in the Suffolk than in the Mouflon.

(From "Growth and the Development of Mutton Qualities in the Sheep.")

Of the bones, the cannon bone grows least (and so is taken as the standard), while the femur grows most. Again the muscles as a whole grow more than the bones after birth, so that, just as the different parts of the animal mature at different times, so the different tissues of the body reach their maximum proportions at different times—the skeleton, as a whole, develops earlier than the muscles, and these again than the fat.

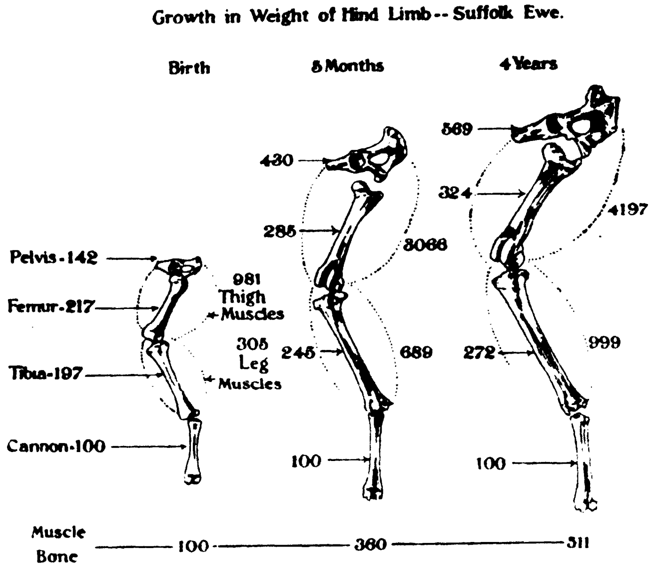

FIG. 99.—THE CHANGES IN THE PROPORTIONS OF THE MUSCLES AND BONES IN THE LEG WITH AGE IN SUFFOLK EWES.

The weights are shown as a percentage of the cannon bone in each animal. The upper bones of the leg (pelvis and femur) grow more after birth than the lower ones (cannon); the muscles surrounding the upper bones increase in proportion to an even greater extent than the bones, and so the proportion of muscle to bone increases with age

(From "Growth and the Development of Mutton Qualities in the Sheep.")

In general, those parts or organs of the animal which are proportionately large at birth, and which mature early, are those which are physiologically essential to the animal—those which are absolutely necessary for the "maintenance" of life: the brain, heart, lungs, etc. Whereas those which develop later are those which are of little importance for maintenance, but are mainly used for "production" (muscle, fat, etc.). When a mature animal is starved, it is these later developing parts which lose the most weight, and the nutrition contained in them is expended to protect the earlier developing vital organs. Just in the same way, when a young growing animal is underfed or put on a "store" diet, the limited supplies of nourishment absorbed are used primarily for the growth of the early developing and vital parts, while the late

developing and economically more valuable parts are those which suffer most. In this way the proportions or conformation of the animal may be changed by the plane of nutrition on which it has been fed.

Fig. 100 shows on the right the normal changes which take place in well-fed Hereford bulls during growth, while on the left the steer at 30 months old, which has been kept on a low store diet, has, in spite of its age, body proportions very similar to that of a well-fed calf at five weeks old, as contrasted with the good development of the steer of 22 months old which had been well fed since birth. In order to show the progress which has been made by breeding, the conformation of a bull of 100 years ago may be compared with that of the bull of to-day.

To make the best selection of animals for early maturity in meat, the plane of nutrition should be so high that it no longer becomes a limiting factor in development, so that animals which are capable of making the best development can be picked out easily, *i.e.*, improvement in breeding should go hand in hand with improvement in feeding. Thus the specialized improved breeds of domestic animals have been evolved in places where the local conditions of feeding have enabled development of the quality desired to proceed unchecked by any limitation in the supply of the necessary foodstuffs required for it. Thus man can, to some extent, mould his animals for productive purposes by the environment which he creates for them.

Organs or parts of the body having their maximum actual growth rates occurring about the same time appear to be correlated in development; thus in cattle and sheep a relatively long neck and head is associated with relatively long legs. The British system of judging meat animals is based on this fact, and more attention is paid to the symmetry of the animal as a whole as a primary factor than to individual points which are secondary. The score card system of judging which considers individual points separately has not been used in practice.

The value of the conformation of the animal to the butcher is shown in the carcass percentage, or weight of meat in proportion to live weight that he has to hang up in his shop. This also bears a relation to the total quantity of edible meat obtained from the animal. For example, from animals of different shapes, as shown in the Suffolk sheep in Fig. 98, the following proportions of carcass and edible meat were obtained :—

Suffolk Sheep—Ages.	Birth.	5 Months.	2 Years.
Lbs. of carcass per 100 lb. of live weight ...	52·6	53·7	67·2
Lbs. edible muscle and fat per 100 lb. live weight	30·0	45·7	61·5
Percentage of fat in the leg of mutton ...	2·9	19·9	37·7

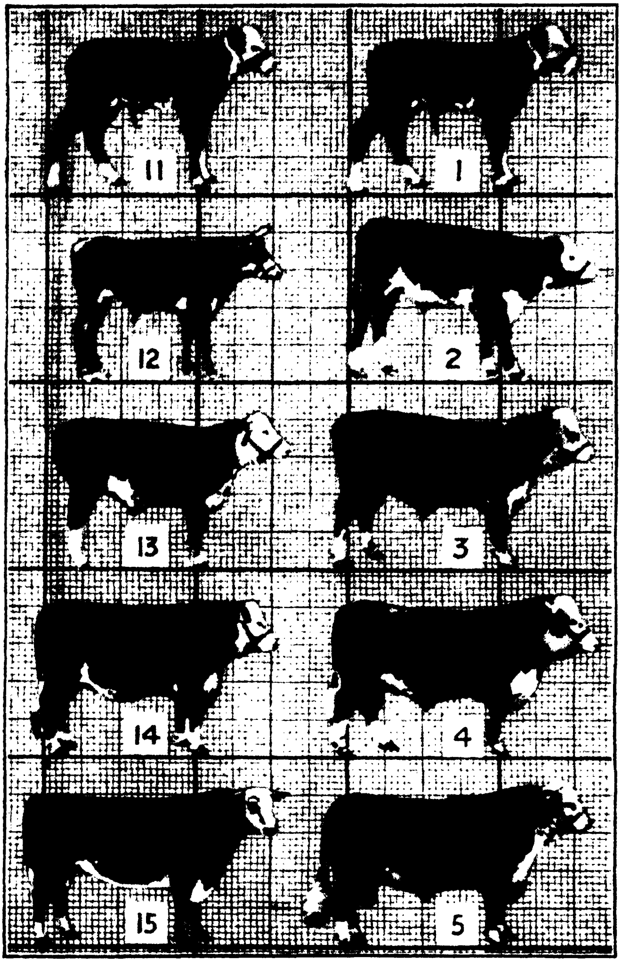

FIG. 100.—CHANGES IN THE PROPORTIONS OF THE BODY IN HEREFORD CATTLE.

(11) Heifer—2 days old.
(12) Steer—30 months old, fed on low maintenance ration.
(13) Steer—11 months, full ration.
(14) Steer—22 months, full ration.
(15) Bull—of 100 years ago.

(1) Heifer—2 days old.
(2) Bull—5 weeks old.
(3) Bull—13 months old.
(4) Bull—22 months old.
(5) Bull—5 years old.

Note the change in the proportions of the bulls with age; the shortness of body in proportion to height in steers as compared to bulls; the effect of a low ration (12) in inhibiting the changes in proportions with age (14); and the improvement in the proportions of bulls (15 and 5) brought about by selection in 100 years.

(From "The Hereford Breed Annual," 1928.)

From these figures it will be seen that, after the offal has been removed and the bones taken out, the butcher has twice as much edible meat to sell from 100 lb. of live weight of an animal shaped like the adult ram as he has from one shaped like the lamb at birth. It will also be seen that the proportion of fat in the leg (a joint which has a composition very near the average of the carcass as a whole) at two years old is too high for modern requirements, that at five months old being just about right. It is difficult to over-fatten a young animal, but with early maturing types it is easy to over-fatten an old one for present day requirements.

Pigs are produced for two purposes: (1) Pork, in which the highest prices are given for pigs of about 90 lb. fasted live weight; and (2) Bacon, for which a pig of about 200 lb. live weight is required. For pork a very early maturing type is wanted which will yield a high percentage of carcass and will have blocky joints at an early age. This type, if kept to bacon weight, tends to accumulate too much fat, for with bacon pigs a large quantity of lean meat with only a small proportion of fat is demanded. Consequently, for bacon pigs a longer and rather later maturing type is required. When pork-bred pigs have to be made into bacon they are better if reared on a low ration, whereas when bacon-bred pigs are to be made into pork they should be fed on as high a ration as possible. An idea of the carcass percentages that may be expected from animals of these types can be obtained from the following average figures of animals exhibited at Smithfield :—

	Age in months :	3	5	7	9	11
Berkshire (Pork)	Live weight—lb. ...	73	102	175	231	248
	Carcass percentage	77·0	78·7	81·1	82·5	83·1
Large White (Bacon)	Live weight—lb.	67	124	230	260	325
	Carcass percentage	73·9	76·9	80·9	81·3	83·5

While formerly in this country the pig was kept mainly for pork production, the recent low price of cereals combined with the growth of the dairying industry has led to the development of bacon production. Although our best breeds and types are as good as any in the world for this purpose, a very large number of the commercial pigs, owing to their former use as pork, are at present deficient in several respects. The chief faults usually found are shortness in length of body, too much fat, uneven back fat, heavy shoulders, thin flanks and soft fat. Fig. 101 shows suitable and unsuitable types for bacon.

Suitable Side—

Weight ... ... 58 lb.

Measurements on cured side (inches)·

Length of middle ... ... (A) 32·0
Thickness of belly ... ... (B) 1·7; (C) 1·6; (D) 1·5
Thickness of flank ... ... (H) 1·0
Thickness of back fat ... (E) 1·9; (F) 1·3; (G) 1·7, 1·5, 1·8

The carcass percentage is raised during the process of fattening; for example, commercial cattle which as stores would kill at 47 per cent. yield 55 per cent. when half fat, and up to 60 per cent. when fat. The carcass percentage is also increased when the animal is

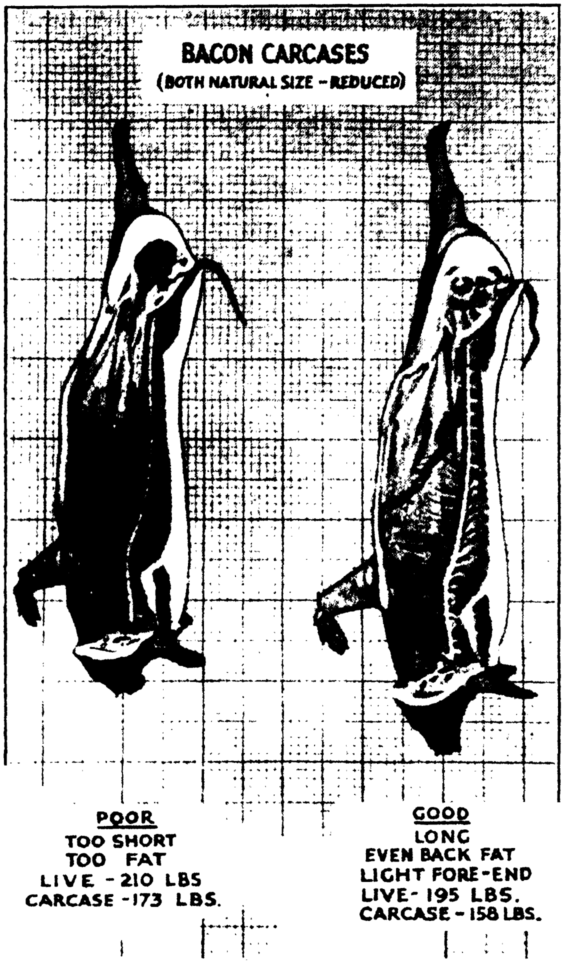

FIG. 101.—SUITABLE AND UNSUITABLE SIDES FOR BACON FROM PIGS OF 200 LB. LIVE WEIGHT.

starved before slaughter, as the stomachs of sheep may, under some conditions, hold up to 10 per cent. of the body weight, but it is the increase in carcass percentage due to conformation which is the important one in live stock improvement.

The most valuable joints of the animal (see Fig. 102), although varying slightly with the species, lie mainly along the back, *i.e.*, in judging an animal for meat the area along the line from the hip bone to the shoulder is most important, and it should be well developed. On the other hand, the lower parts of the legs and neck are relatively low-priced joints, and so in a good meat animal should be comparatively small.

In pigs, sheep and cattle, as the animal grows up the proportions of the more valuable to less valuable joints increase. This does not mean, however, that animals should be killed at older ages to get the best quality meat, for other factors such as toughness increase

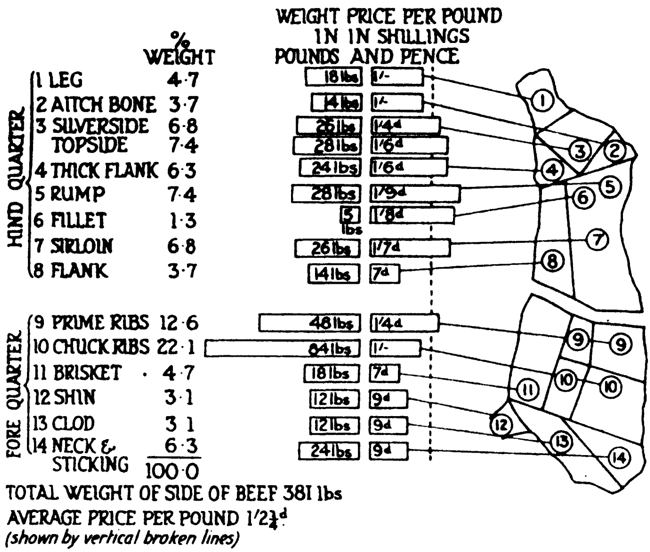

FIG. 102.—THE VALUE AND PROPORTIONS OF THE DIFFERENT CUTS OF BEEF.

Note that the most valuable joints lie along the back and in the hind-quarter rather than in the forequarter.

(From " The Butcher's Shop.")

with age, and the public demand is now for smaller joints. What it does mean, however, is that animals should be bred which will go through the changes in the proportions of the body more quickly, and attain mature proportions at small weights and early ages. One of the chief problems of the butcher in England is to sell all the second and third quality joints, and these he often has to clear at a loss especially in the summer months, as they are stewing joints for which there is little demand then, whereas he can always sell the first quality as roasting joints.

Another factor affecting the quality of meat is the distribution of fat in the body. While any pound of fat gained by the body

takes the same amount of food to produce it, its value when sold is very different according to where the fat is deposited in the body. Thus fat deposited within or over the muscles improves the keeping value and quality of the meat on cooking, and is the main object of the fattening process in animals. It is consequently much more valuable than the fat deposited in the mesentery (gut) or omentum (caul) which has only a low value as tallow or suet. The same relations between age, breed and feeding exist here as in the other factors affecting quality ; fat is deposited in the various organs of the body in a definite order, and this order remains the same whether increased fatness is due to increasing age of the animal, to breed improvement, or to the actual process of fattening. When bullocks and sheep are first put up to fatten very little external change is seen, the fat being added to the abdominal organs ; after a few weeks, however, it is gradually deposited in the subcutaneous layer over the surface of the body muscles, giving, when present in sufficient quantities, a smooth rounded outline to the animal. If this fat layer is unevenly distributed it will be too thick in some places (pinbones in bullocks ; loin in sheep ; shoulders in pigs) by the time it is the right thickness in others, so that if the animal is fattened sufficiently to cover and make saleable the low-priced joints (neck, lower parts of legs), some fat will have to be cut off the thick places ; fat so removed is of offal value only, and is produced at an economic loss. Lastly, fat is deposited between the different muscles, and then within the muscles (marbling fat). A similar order of distribution of fat occurs with increasing age and with breed improvement : young animals have less marbling fat than old ones, while if an animal of a dairy breed, such as the Jersey, is put up to fatten, it will store up large quantities within the abdomen, where it is of little value, but only at a very high degree of fattening will it add much subcutaneous fat over the muscles.

Cattle fattened on carbohydrate foods, such as roots in winter, tend to give fat rather too hard for the public taste, and are much improved by finishing off with linseed cake, which softens it ; on the other hand, with grass fed bullocks in summer the fat is too soft, and is much improved by finishing on carbohydrate meals or cotton cake, which harden the fat. Foods which contain fats tend to produce soft fats in pigs, and should not be used towards the end of the fattening period : barley meal and whey produce a very firm carcass.

The flavour of meat is closely associated with its colour. The muscles of calves are pale and comparatively flavourless, and the colour and flavour develop with age. It is possible to develop too much colour and flavour in meat so that it becomes objectionable ; thus the meat of old males and old animals in poor condition, or after much exercise, is too dark in colour and strong in flavour to suit the public taste. Castration decreases the colour. The colour is due to hæmoglobin, and in the production of veal, where its absence is required, care should be taken that the animal does not

obtain feeds containing iron: milk contains very little iron, and therefore gives a pale (dairy fed) veal or pork. The feeding of oats, on the other hand, increases the colour, and may be of use in adding to the flavour of baby beef.

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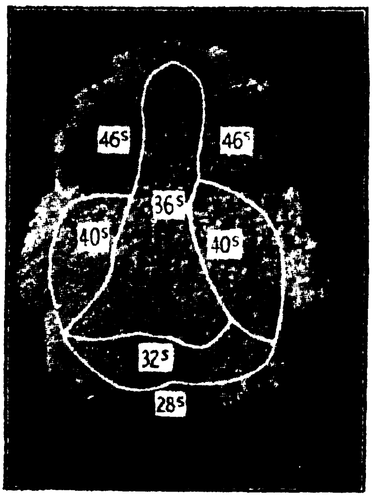
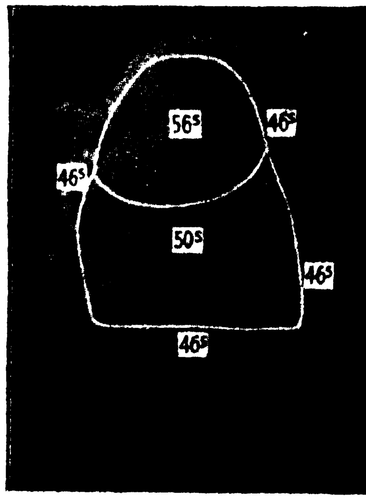


28's — the lower, coarse quality grades.

(a) *Cheviot*.—The fleece is not only of coarser quality, but requires sorting into five different grades.



56's — the best, fine quality grades.

(b) *Southdown*. The fleece is not only of fine quality, but requires sorting into only three grades.

FIG. 103.—EXAMPLES OF THE VARIATION THAT EXISTS BETWEEN FLEECES IN THE DISTRIBUTION OF THE DIFFERENT QUALITIES OF WOOL.

(From "Development of Peru as a Wool-growing Country." A. F. Barker.)

Wool.—The value of wool depends on the articles into which it can be manufactured. The classification of wools usually adopted is, proceeding from the most to the least valuable: (1) "fine wools," the best coming from the Merino, while the coarser sorts of fine wools are produced by the Down breeds in this country: these wools are usually comparatively short, and frequently go under the name of short wools; (2) "long wools," which are coarser but longer and frequently have a lustre or sheen, the value of which depends on the fashions in vogue at the time; and (3) "coarse wools," or

Mountain wools, which often contain many hairs or kemps, and the lower qualities of which are only of use for carpet-making.

The fineness of the fibre, on which the main classification of wool is based, varies in different parts of the same fleece, so that the fleece has to be sorted out into different qualities before manufacture. Consequently the more uniform the fleece is the higher

Wool.	From.	To.	Average diameter.
	In.	In.	In.
Blackface	$\frac{1}{1312}$	$\frac{1}{147}$	$\frac{1}{469}$
East Indian (Karachi)	$\frac{1}{1500}$	$\frac{1}{184}$	$\frac{1}{521}$
Kenya	$\frac{1}{1750}$	$\frac{1}{190}$	$\frac{1}{629}$
Syracuse	$\frac{1}{1500}$	$\frac{1}{283}$	$\frac{1}{682}$
Wensleydale... ...	$\frac{1}{1312}$	$\frac{1}{388}$	$\frac{1}{647}$
Southdown	$\frac{1}{1750}$	$\frac{1}{477}$	$\frac{1}{879}$
Merino (Camden) ...	$\frac{1}{2625}$	$\frac{1}{875}$	$\frac{1}{1363}$

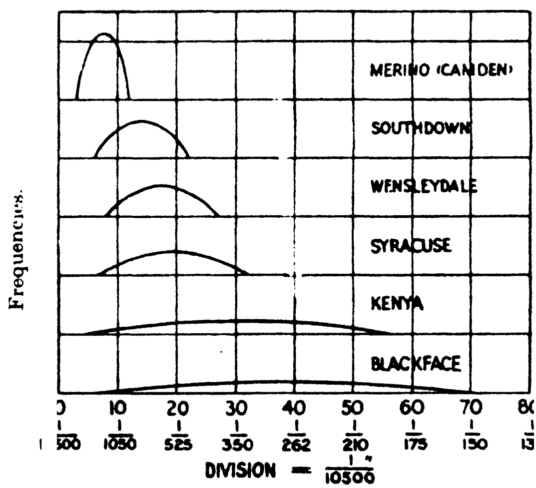


FIG. 104.—THE VARIATION IN THE THICKNESS OF THE WOOL FIBRES IN DIFFERENT TYPES OF FLEECE.

Not only are the fibres in the Merino fleece on the average finer than those of the Blackface, but the variation in the size of fibre is much less: this adds greatly to the value of the wool.

(From Report 24th International Sheep-breeders' Conference, Chester, 1925.)

will be its value : a good Merino fleece may only need sorting out into two or three qualities, whereas a bad Down or Longwool may have to be divided into five or six (see examples in Fig. 103, 64's being the highest quality).

The finest wool is situated over the shoulder, while the coarsest is usually found on the britch. Uniformity of fleece is usually associated with uniformity and fineness of the wool fibres, and selection for this is the main requirement in the improvement of British wools, as the examples on previous page show.

The fine fibres consist of cortical tissue and scales only, and have a relatively high tensile strength, whereas the coarser fibres, and particularly the kemps, have a central medullary space in addition, which reduces the strength and makes them brittle. Another factor which affects the quality of wool is the absence of weak spots in the fibre such as may be caused by checks in growth due to illness (4th stomach worm, garget, etc.), or to a period of bad nutrition ; in extreme cases the wool, especially that on the belly, tends to break off and be shed before the time of clipping.

The properties of the fibre which affect its felting or binding together are also of importance ; the greater the " crimp " or number of waves per inch of fibre length the better will the wool felt on manufacture. The projection of the outer cuticle scales of the fibres also assists in binding the fibres together, and the greater the number and the more they project the better for this purpose will be the wool. There is with both these factors a partial correlation with fineness. The " lustre " of such wools as the Wensleydale and Leicester is due to the reflection of light caused by closely adpressed scales.

The " yolk " or grease, an oily secretion produced from the sebaceous glands at the sides of the hair follicle, acts as a preservative of the fibre ; the relative amount of grease usually increases with the fineness of the fibre, and may at times be troublesome in causing dust to adhere to the fleece. The loss of weight due to yolk, which takes place on washing the fleece, may vary from about 16—24 per cent. with English Longwools, and 20—30 per cent. in English Downs to 40—70 per cent. in Merinos. After washing sheep a day or so should be allowed to elapse before clipping, in order that the yolk may rise in the wool, otherwise the wool will be harsh to the touch, and will not retain its elasticity and strength so well on keeping. While whole black or coloured fleeces are of value when in bulk, the presence of a few pigmented fibres mixed in a white fleece detracts considerably from the value, for such fibres like kemps take the dye differently and spoil the cloth : their detection is easier in the lamb than in the adult.

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Eggs.—At times when the price of corn is low it may be cashed more profitably by the production of eggs. The supply, and so the price, of fresh eggs varies considerably with the time of year; in successful production, therefore, it is necessary to overcome these natural tendencies in output. That climate, and probably more especially light, are the main factors is seen by comparing egg production curves of hens in England with those in Australia, where the times of the seasons are reversed (Fig. 105):—

Number of eggs laid per bird each month.

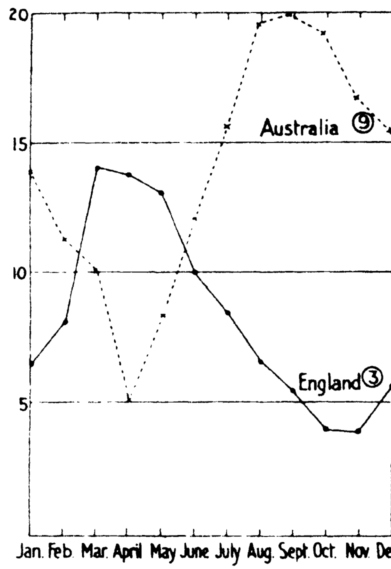

FIG. 105.—THE SEASONAL VARIATION IN EGG PRODUCTION IN THE FOWL.

The seasonal conditions, and particularly hours of daylight, affect the rate of egg production; the maximum production in Australia occurs in September, corresponding to our spring.

(From "Züchtungskunde," 3, 1928.)

This conclusion is borne out by the study of egg production in other countries where the duration of daylight differs. The factors which make for high yearly production (200 eggs or over) all tend to make the seasonal differences smaller, so that higher production whether produced by breeding, feeding or management makes the supply more uniform throughout the year, and consequently the average price better. Egg records (by trap-nesting), laying trials, and selecting cocks from high-producing hens form the main basis of breed improvement. Generally speaking, there is a correlation between early maturity (age at first egg laid) and total yearly production, so that where egg records are not kept selection is best based on those which begin to lay early. In the yellow shanked

breeds (White Leghorns) the yellow colour is drawn upon to produce the yellow colour of the yolk, and so the birds which have been laying heaviest may be picked out by the paleness of their colour in the spring. Good feeding (or rations high in animal protein), provision of shelter, and lighting the houses so as to give the hens a longer day in the winter months, all tend to increase production. The optimum time for the hatching of pullets depends on the breed, it being arranged so that the time of the first egg laid occurs in October; this usually means hatching in February or March for the heavy-sitting breeds (Light Sussex, Wyandottes and Orpingtons, etc.), and in March or April for the light non-sitting breeds (Leghorns, Minorcas, etc.).

Ducks of the runner or light varieties are being increasingly used for egg production, as they lay well in the colder and wetter months in the year if properly managed.

CHAPTER XXVI.

DAIRY PRODUCTS.

Location of Industry.—In former times dairy farming was practised chiefly in the western part of Great Britain, whereas the regions of less rainfall in the east were devoted to arable farming, although there were some exceptions, such as the native district of the Red Poll cattle. However, the most important dairying districts were located in areas of abundant grass, such as the well known cheese-making counties of Somerset and Cheshire.

During the present century numerous farms on which cheese used to be manufactured have been devoted to the production of milk which is immediately dispatched for liquid consumption. This change of policy is chiefly due to (1) an increased demand for liquid milk caused by the growth of population; (2) improved transport; and (3) the fact that large quantities of cheese are now imported, with the consequence that the price of English cheese is profoundly influenced by that of the imported product. Concurrently with the increased production of milk for liquid consumption in old established cheese-making areas, dairy farming has been largely taken up in almost all other parts of the country, and milk production is now associated with many systems of farming, varying from "all-grass" farms to farms on which the cattle are chiefly "green-soiled" in paddocks or yards with crops grown on the arable land.

Systems of Dairy Farming.—In most large areas devoted to dairy farming different systems are practised in different localities. For instance, in upland districts the rearing of dairy cattle may be a speciality and some of the cows in milk will suckle a number of calves in succession, while other cows will be milked in the ordinary

manner. Formerly, butter was made in such localities, but butter-making is no longer remunerative, and improved motor transport facilities have enabled the milk to be sent to milk factories, or direct to dairy firms in towns. The majority of the cows in such a district will be heifers or young cows, and as such they are sold to farmers in areas of more intensive production.

Adjacent to such an upland rearing district, but at a lower altitude, there usually lies a district which makes the production of milk a primary object instead of secondary as in the former case. Most of the heifers and young cows sold from the rearing district come into this area, although some heifer calves may be reared. Such a district may be devoted to the manufacture of cheese although the sale of whole milk frequently is the primary object.

A third system of dairy husbandry may be described as "suburban dairying"; as the name implies, this system is employed near large centres of population, where both the land and labour are costly. Very few calves are reared and mature heavy yielding cows are bought to replenish the herds. Many farmers in such districts operate retail milk rounds and combine the business of milk distribution with farming. Only a high level of production can be profitable under these conditions and scarcely any dairy products are manufactured. As most suburban dairy farmers aim at maintaining a constant production, they frequently purchase fresh cows to rectify falling supplies. This procedure often introduces serious ravages in the herd from contagious abortion brought about by the introduction of infective cattle. In fact, on many farms in the industrial areas, no breeding of any kind is practised, and mature cows are bought just after calving and are sold as fat animals at the end of the lactation period. It should be understood that contagious abortion, like bovine tuberculosis, is often spread by failure to realize or apply adequately the rules of hygiene which relate to the spread of infection.

Milk Recording and Rationing.—These practices are now considered essential to good dairy herd management, for it is impossible to feed cows according to their milk yield unless the production of milk is first determined. In England and Wales almost every county possesses a "Milk Recording Society" of dairy farmers and every member weighs the milk from all cows, either at each milking or on one particular day each week. About every six weeks an officer of the society visits the farm to check the weighings, the recording and the arithmetic, after which he initials the registers if they are in order. The English system of milk recording is as follows: all milk is weighed in an accurately tared pail, as illustrated in Fig. 106, and then the weight is recorded on a weekly milk return.

Every week the quantity of milk produced by each cow is determined and transferred to the annual register; if the milk has only been weighed once then this weight is multiplied by seven and the product transferred to the register. Obviously the system of

weighing all the milk produced gives more accurate results and, if the work is properly organized, little time is required once the staff has become accustomed to the routine. All such occurrences as calving, abortion, heat periods, date of drying off, illnesses, etc., should be noted in the column for remarks in the annual register. The weight of the milk is taken in preference to the volume, because it can be determined with greater ease and accuracy and with less likelihood of the milk being contaminated. A gallon of milk weighs about 10·32 lb. or approximately $10\frac{1}{3}$ lb. Milk recording is the first practical step of up-to-date dairying.

The usual practice in rationing dairy cows is to feed all cows, whether dry or in milk, a basal ration equivalent to the maintenance requirement plus that for one gallon of milk, and to all cows yielding more than one gallon daily a "production ration" of concentrates in accordance with the amount of milk produced. The weight of cake and meal mixture to be fed is marked up near each animal, so that the herdsman can easily see how many measures of meal must be given to each cow—in practice, the meal mixture is usually ladled out in a measure containing a pre-determined weight, *e.g.*, three pounds.

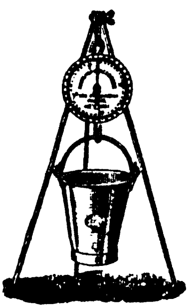

FIG. 106—MILK RECORDING BALANCE.

Milk recording societies also provide other facilities, such as butter-fat testing and the tattooing of calves. In the former case the milk recorder takes samples of thoroughly mixed milk and forwards them to a laboratory, and in a few days time the milk recording society sends the results to the farmer who should enter them in the annual register. As regards the marking of animals, this is more easily done with young than older cattle and every cow in a recorded herd must have a permanent number tattooed in one ear. It is also necessary to have adequately marked every animal in tuberculin tested herds which produce either Certified or Grade A (Tuberculin Tested) milk, and there is no more convenient way than to use the milk recording society's tattoo marks for this purpose.

BENEFITS OF MILK RECORDING.—The most obvious benefit is that the production of each cow is known and the unprofitable yielders can be detected and disposed of ; this knowledge is particularly useful with heifers. In the pedigree herd books of the dairy breeds of cattle the inclusion of milk yields gives valuable information to readers. Herd books are of two kinds, closed and open ; an "open" herd book for dairy cattle is one which admits cattle from non-pedigree origins, subject to certain conditions and standards of milk production. Coates's Herd Book, which is the pedigree book of the Shorthorn breed of cattle, is an open book and dairy cattle may be entered either by means of the Shorthorn Society's Grading Register or by the more usual course of the Dairy

Shorthorn Association's Year Book. In the latter case the requirements are as follows: the milk yield must have been good—at least 600 gallons must have been given in 315 days by a heifer, or 800 gallons by a cow—and the animal must be of good Shorthorn type and character. The system is to breed in direct female line from such a foundation cow, and the female calf by a pedigree Shorthorn bull of the fourth generation may be entered in Coates's Herd Book, provided that pedigree Shorthorn bulls have been used throughout. It is customary to publish in the Dairy Shorthorn Association's Year Book the milk yields of animals which are being graded up.

Two other ways in which effective use may be made of milk records are given below. The weak spot in the breeding of dairy cattle in many herds is the class of bull used. When a pedigree bull is about to be purchased an "extended pedigree," including every ancestor for four or five generations, should be prepared and every available milk record for all the female ancestry should be

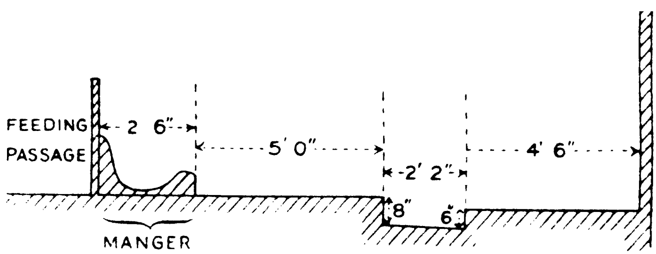

FIG. 107. DIAGRAM OF CATTLE STANDINGS.

included. In no other way can a satisfactory estimate of the value of the bull's ancestry be formed. Finally, if a bull has been kept sufficiently long, and it is found that the milk yields of his offspring exceed those of their dams, then that bull should be retained as long as possible, assuming, of course, that there is no serious disqualification in other directions. In a similar way the butter-fat transmitting powers of a bull may also be studied.

CONSTANT OUTPUT OF MILK.—Studies of milk records have shown that a uniform quantity of milk can be produced throughout the year from a healthy herd of good yielders. As an instance the following arrangement of calvings in a herd of 20 cows should produce a uniform flow of milk, provided that effective services take place about twelve weeks after calving, and the cows are dry about nine weeks. Taking the months in their order, commencing with January, the monthly calvings should be as follows—none, two, one, one, two, one, three, three, one, three, none, three. Preferably, some of the heifers should calve during July and August so that they may ultimately become autumn calvers should some service periods be missed.

Buildings Required on a Dairy Farm.—In Britain the essential buildings are byres for the cattle and a dairy for the manipulation of the milk and the cleaning of utensils; food stores, barns and cattle yards are important accessories to the above but need not be considered here. The buildings should be near the fields, and all roads and passages should be well maintained and clean, otherwise more time is required for grooming.

In the past too little attention has been paid to the application of the laws of hygiene in the construction of cowsheds, and usually the chief object has been to keep the cattle warm to the detriment of adequate ventilation, air space and window space. It is now realized that cattle are healthier when they are given more light and air and that this is in no way detrimental to either the quality or quantity of milk produced, provided the cattle are accustomed to such conditions. Every modern byre should be provided with at least the following amenities per cow:—800 cu. ft. of air space—not counting any height above 16 ft., 40 sq. in. of ventilation area and 3 sq. ft. of window space. Furthermore, the inner walls should be rendered smooth to a height of 6 ft. with non-absorbent cement plaster and the floors should be of impervious material.

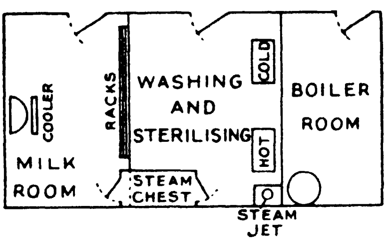

FIG. 108.—SKETCH PLAN OF DAIRY, GIVING POSITIONS OF PLANT.

If the standings are of the right dimensions for the size of cattle kept, they help the cattle to keep clean. The mangers should be on the floor level, so that the cattle can place their heads over them when lying down; the system of tying should be one which gives freedom of movement of the head and neck, but which restricts the backward and forward movement of the cattle. During recent years the American system of metal neck stanchions, and partitions of tubular metal, has become popular in Britain, because it reduces the labour bill for grooming. If the standings are of the right length for the breed then almost all the dung should fall in the gutter, while the cattle can comfortably stand on the raised portion. For Shorthorn cattle of average size each standing should be 7½ ft. long and 3½ ft. wide as shown in diagram 107. In sheds with double rows of cattle it is best to instal them on the "tail to tail" principle, as this method reduces the chances of infection with respiratory diseases and facilitates cleaning.

THE DAIRY should preferably have a north-east aspect if it forms part of a larger building, but in all cases it should be near the byres and all paths and roads leading to it should be clean and dry. The dairy should have plenty of light, concrete floors and walls that have been cemented smooth or tiled internally. A really

modern farm dairy consists of three rooms, viz., a room for cooling milk and storing clean utensils, a washing room equipped with washing vat, steam sterilizing chest and steam jet, and a boiler room with no direct communication with the other two rooms.

Manipulation of Milk and Utensils.—The key to successful dairying is cleanliness, which involves not only keeping visible dirt out of milk, but also microscopic organisms which reduce the keeping qualities of milk and milk products. Good dairy practice, therefore, aims at eliminating all forms of contamination from the milk utensils and the milk itself. Before milking commences the cows should be groomed and then milking should be performed with clean hands into domed pails (Fig. 109). As an aid to keeping the cows clean, the hair on the udder, flanks and tail should be shorn. The milkers should wear clean overalls and the first stream of milk from each teat should be rejected because the first drawn milk often has a high bacteria content through the ingress of bacteria into the teat canal ; it is at this stage that the milker should detect even mild attacks of mastitis or "garget," by the "feel" of the udder, and milk from even slightly affected udders should not be included with the bulk ; such milk is more alkaline than normal milk and in the manufacture of cheese renders it difficult to secure a satisfactory curd. Moreover, cows with any udder infection should always be milked last so that milkers, or mechanical milking units, cannot carry contagion from cow to cow.

FIG. 109.—COVERED OR DOMED MILKING PAILS.

HAND MILKING.—The cow should be approached quietly with a gentle word giving warning of approach and then milking should be carried out quietly, quickly and thoroughly. A good milker will milk from seven to ten cows in an hour and will secure from 2 to 4 lb. of milk per minute according to the yield and ease with which the cows may be milked ; he should not rest his head against the cow and should keep his shoulders still, and there should only be gentle movements of the fingers, wrists and muscles of the forearms. The forequarters should be milked first, the teats grasped with the full hand where possible and the milk ejected by applying pressure commencing with the thumb and forefinger and extending downwards, but without actually pulling the teats downwards. Often it is advantageous to apply a gentle upward pressure to the udder before commencing to squeeze and thus help in the more rapid emptying of the milk cistern. If the teats are not very long they should not be grasped in the "full hand" manner, but between the thumb and the first two fingers, and in almost all cases it is necessary to finish each cow by the "stripping action" which consists of forcing the last drop of milk out of the teats by squeezing them between the thumb and forefinger as they are moved downwards towards the nipple. Cows

should always be stripped thoroughly as the strippings are very rich in butter fat and failure to withdraw all the milk during milking is a frequent cause of cows drying off too soon.

Mechanical Milking.—Successful mechanical milking is now an accomplished fact and with some types of machine it is possible to produce milk of the highest hygienic quality, provided that the milking units are properly washed and sterilized by steam. One operator and a youth can control five or six units and do the necessary stripping. If it is the object to produce Grade A milk by machine the cows must be groomed and washed as for hand milking and the stripping should be done with a covered pail; although some machines will strip out the cows it takes considerable time and is better done by hand. Most milking machines operate at about 50 " milk suction " pulsations per minute and each unit will milk a cow in about the same time as a good hand milker. It cannot be emphasized sufficiently that scrupulous attention in washing and steam sterilizing must be paid to every metal or rubber accessory which touches the milk if satisfactory keeping qualities and low bacteria counts are to be obtained.

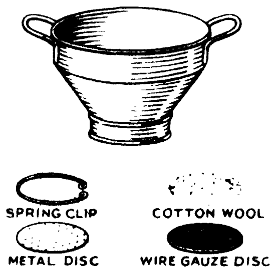

Fig. 110.—Milk Strainer and Component Parts.

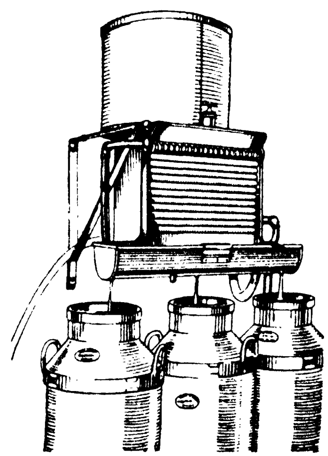

Fig. 111.—Milk Vessel, Refrigerator, and Milk Equalizer.

Treatment of Milk.—As soon as the milk has been drawn from the cow it should be removed promptly from the byre, as milk quickly absorbs odours and so becomes tainted. After the weight has been recorded the milk should be strained. Frequently the milk is sieved through ordinary wire gauze of fine mesh, or through filter cloth, but the best strainers (Fig. 110) are those containing a pad of prepared cotton wool which rests on gauze and removes the smallest particles of sediment. It should be recognized that the

presence of sediment on the filter disc is really an indication of faulty methods.

Cooling of Milk.—Where the milk is sold in bulk it is necessary to reduce its temperature promptly to prevent premature souring. This is done by passing the milk from a reception tank over the corrugations of a "refrigerator" (Fig. 111), which consists of a number of super-imposed tubes through which cold water passes from bottom to top. The milk should be cooled to 50° F. if possible, or alternatively to within 1° F. of the initial temperature of the cooling water; usually about four gallons of water are used to each gallon of milk. The milk generally runs direct from the refrigerator into tankards or churns of either 10 or 17 gallons capacity; if several churns have to be filled and the freshly-calved cows are milked first, it frequently happens in early summer that the milk in one or two churns may contain less than the standard of 3·0 per cent. butter-fat, whereas in other cans the milk may be well above the 3·0 per cent. limit. This difficulty can be overcome by filling a number of churns—preferably all of them—simultaneously by means of a "milk equalizer" (Fig. 111), thus ensuring a more even distribution of butter-fat in the churns.

If the milk is to be separated for butter-making or is to be manufactured into cheese, it should not be cooled. Cooling prolongs the keeping qualities of milk because low temperatures inhibit the multiplication of micro-organisms, and milk is turned sour through various forms of lactic acid bacteria converting the lactose into lactic acid. Temperatures above 60° F. are very favourable for the propagation of these souring organisms.

Cleaning of Utensils.—The real object in cleaning all dairy utensils is to remove not only the visible milk residues, but also the very thin invisible layer of greasy material which acts as a fertile breeding place of those organisms which are particularly harmful to the keeping properties of milk. The correct technique in cleaning dairy utensils, which is one of the most important operations in dairying, is as follows: immediately after use all milk residues should be rinsed away with cold water and then the utensils should be scrubbed in hot water containing washing soda, which should remove the last traces of caseinogen and fat. The final operations should include a rinse in clean, hot water to remove any remaining washing powder, and sterilization in a steam chest, or over a steam jet, to destroy germ life. The usual way of finishing the washing process on farms is to "scald" the utensils, but "scalding" is not nearly so efficient as "steaming" them. The most frequent direct cause of premature souring of milk is inefficient cleaning of the dairy utensils and particularly insufficient steaming or scalding. In the production of graded milk, where bacterial counts must be kept low, it is essential to sterilize all utensils, sieves, udder-cleaning cloths, etc., by steam, preferably in a chest in which the steam is not maintained under pressure so that the latent heat of vaporization may be utilized.

Modern Conception of High Grade Milk.—In former times milk was considered to be "clean" if it proved to be free from sediment upon filtration through cotton wool pads, but now a low content of bacteria is required in addition. Where the dairy utensils are not sterilized, high germ contents are caused by the inoculation resulting from the multiplication of bacteria on the walls of the utensils between milkings, and by the bacteria contained in the particles of dung, dust, etc., which gain admission. The content of *Bacillus coli* is a valuable index of the "cleanliness" of a sample of milk, as these organisms are usually associated with excreta, and it is usual to judge of the hygienic quality of milk by a consideration of the content of Coli bacilli in conjunction with the bacteria count, the bacteriological testing being performed when the milk is from 24 to 30 hours old and has been kept at normal temperatures.

Several "grades of milk" are permitted by law in Great Britain; licences to produce the two highest grades, Certified and Grade A (Tuberculin Tested) milk, are issued by the Ministry of Health, whereas the County Councils grant licences to produce Grade A milk, as in this case the cows are only clinically examined at quarterly intervals by veterinary surgeons. In all grades the premises, cattle and methods of production, are subjected to inspection and the milk has to conform to stringent regulations concerning the content of bacteria. All cattle producing Certified and Grade A (Tuberculin Tested) milk must pass the prescribed tuberculin tests every six months in addition to clinical examination.

Success in the production of graded milk can only be achieved by careful attention to all details which contribute to a low bacteria count and so to long-keeping qualities. In fact, many producers of high-grade milk have installed units for mechanical refrigeration by means of "brine cooling," etc., since these installations can now be purchased at reasonable prices. Even where mechanical refrigeration is practised with graded milk, every utensil should be sterilized with steam to complete the cleaning processes.

Composition of Milk.—Milk has no fixed composition, and the milk produced by different species of mammals contains varying proportions of the main constituents which are common to all kinds of milk. The chief constituents of milk are water, milk fat, milk sugar or lactose, the mineral portion or ash and the proteins consisting of caseinogen (often loosely referred to as casein), albumin and a little globulin. The globules of milk fat are in suspension as an emulsion, the lactose and part of the ash are in true solution, and the caseinogen and part of the ash are in colloidal solution. It will be realized, therefore, that the chemical and physical composition of milk is very complex.

Rapid Analysis of Milk.—Formerly, considerable reliance was placed in the results given by the "creamometer" which is merely a graduated glass cylinder; milk was poured into the cylinder and after the cream had risen the percentage of cream was read.

It is now known that the percentage volume of cream is not directly proportional to percentage of butter-fat.

Accurate fat determinations are easily made by the "Gerber test" which is used throughout Europe, or the somewhat similar "Babcock test" which is preferred in America. To carry out the Gerber test a special test bottle or butyrometer is used; into this is placed 10 m.l. of sulphuric acid of 1·82 specific gravity, 11 m.l. of milk and 1 m.l. of amyl alcohol; a rubber stopper is then inserted, and the butyrometer is shaken until the sulphuric acid has broken down the fat emulsion by digesting the caseinogen. After the test bottle has been whirled rapidly for several minutes in a centrifugal machine it is removed and heated to 150° F. in a water bath, and the volume of the solution of milk fat in amyl alcohol is read off on the scale provided, thus giving the percentage of fat (Fig. 112).

In addition to the fat determination the specific gravity of the milk at 60° F. should be determined by a special form of hydrometer known as a "lactometer." The average specific gravity of milk at 60° F. is 1·032 and the last two figures are known as the "degrees of specific gravity." Numerous formulae have been calculated which enable one to deduce the percentage of total solids or non-fatty solids if the fat percentage and specific gravity at 60° F. are known. Richmond's formula, given below, is one of the best known and is also easily used because the calculations can be rapidly done on a special slide rule. Richmond's formula is

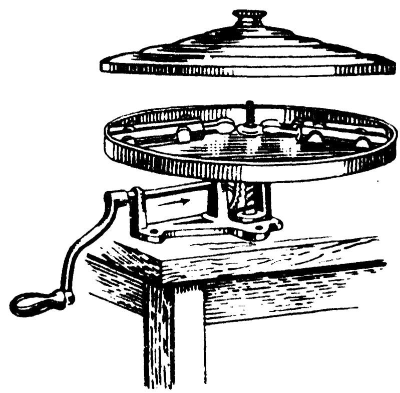

FIG. 112.—GERBER MILK TESTER.

$$T = \frac{G}{4} + \frac{6}{5}F + 0{\cdot}14$$

where T and F are the percentages of total solids and butter-fat respectively, and G is the degrees of specific gravity recorded.

It is not possible to estimate the quality of milk by the lactometer alone; the fat percentage must be considered with it, as must be evident when it is realized that the addition of water or cream to a sample of milk both reduce the specific gravity of the sample.

COMPOSITION OF MILK.—In farming practice the quality of milk is affected by several factors, the most important of which are the season of the year, stage of lactation, length of intervals between milking, efficiency of stripping and breed of cow. The fat percentage is liable to much greater fluctuations than the non-fatty solids. In general, the percentage of fat is high from November to January, rather lower from February to April, low from May to

mid-August and higher again in September and October; the solids-not-fat content varies less, but is often lowest in July and August and highest from November to January.

For the first two or three weeks after parturition the fat percentage is irregular from day to day and may be very high, but when the daily yield of milk is at its highest from the fourth to the sixth week after calving, the fat percentage is at its lowest, after which it gradually rises until the end of the lactation. In ordinary practice the fat content of the morning's milk is lower than that of the evening's, and as the night interval between milkings becomes longer and the day interval correspondingly shorter, so does the variation increase between morning's and evening's fat percentage. The efficiency of the milkers is very important, since careless or inefficient milkers may not obtain all the strippings, which frequently contain 8·0 per cent or 10·0 per cent. of butter-fat. Jersey and Guernsey cows give milk very rich in fat, while some other breeds, like British Friesian cows, give larger quantities of milk containing a lower fat percentage.

THE LEGAL "STANDARD."—In Great Britain if milk contains less than 3·0 per cent. butter-fat or 8·5 per cent. non-fatty solids, it is held to have been adulterated until the contrary be proved. Usually there is little difficulty in keeping the content of non-fatty solids above 8·5 per cent., but in May or June in herds containing many recently calved cows milked after irregular intervals, the morning's milk frequently contains less than 3·0 per cent. butter-fat. To guard against this contingency it is always advisable to milk the heaviest yielding cows last at night and first in the morning.

The composition and appearance of milk is very important when milk is sold in bottles, as customers like to see a deep layer of cream on the surface; they also prefer milk possessing a rich yellow colour like that given by cows of the Channel Island breeds. Greater attention to the butter-fat content of milk would also well repay cheese-making farmers as the elimination of cows giving milk of low fat content is the easiest way of increasing the return of cheese per gallon of milk, since cheese contains such a high percentage of butter-fat.

ABNORMALITIES OF MILK.—The milk yielded directly after parturition is called "colostrum," and is intended by nature as the calf's first food. It is a yellow or brownish, viscous fluid, rich in antibodies which help to build up quickly the calf's resistance to disease. Colostrum may contain as much as 30 per cent. total solids and 15 to 20 per cent. of proteins; the usual test for colostrum depends upon the fact that heat causes the colostrum to coagulate on account of the very high content of globulin. The milk produced for at least four days after calving should not be used for consumption or dairy purposes.

During the late summer months some farms are troubled by "ropy milk"; some hours after milking the milk becomes viscous

and may be drawn out in long threads or "ropes" as a result of bacterial action. The origin of these germs is frequently polluted water and marshy pastures, but all utensils and cloths are liable to become contaminated. The remedy is to sterilize by steam all utensils, sieve cloths, etc., and to clean thoroughly all cows before milking.

When an udder or quarter thereof suffers from mild inflammation the milk frequently may appear normal; tests indicate, however, that such milk is abnormally alkaline and that on the addition of

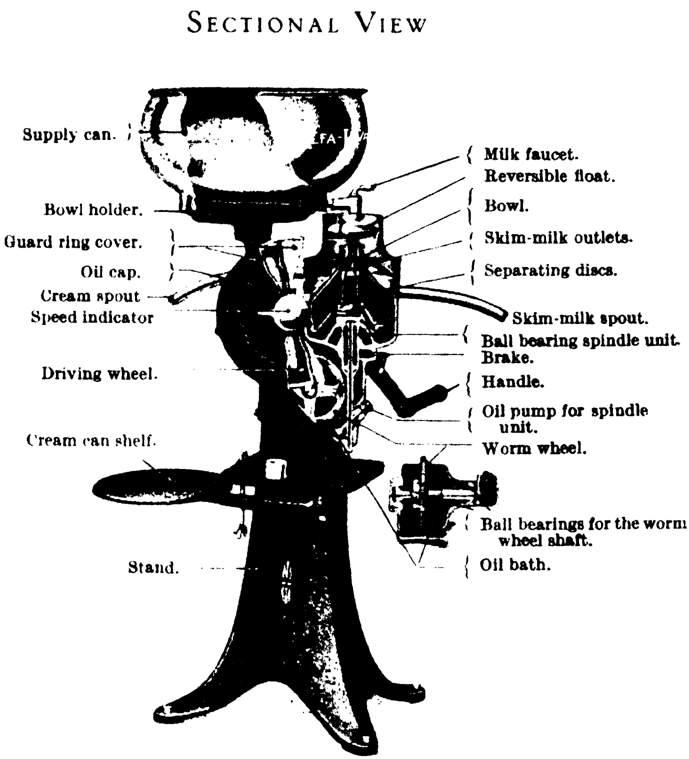

FIG. 113.—ALFA-LAVAL MECHANICAL MILKING UNIT.

rennet it coagulates slowly and forms a slimy, unmanageable curd during cheese-making operations.

TAINTS OF MILK are usually caused by the action of bacteria on the milk under favourable conditions of temperature: "cleaning swabs" which have not been sterilized or scalded frequently carry such contamination. If cattle eat grass or hay containing garlic, mint, wild onion or stinking mayweed, the milk may possess an obnoxious odour and flavour. The feeding of unwilted sugar beet tops, or beet pulp which has been soaked in beet molasses, sometimes

produces an odour and taste of fish owing to the formation of *trimethylamine. Recently, too, it has been realized that exposed surfaces of copper may act as a catalyst in the oxidation of certain constituents to form an oily or fishy flavour in milk or milk products.*

Separating of Milk.—*On farms where a trade for cream exists,* or where butter is made, the milk is separated by mechanical means into cream, and the by-product, separated milk, which is usually fed to calves and pigs. Formerly the milk was set in shallow pans and the cream skimmed off after 24 or 36 hours, but this practice is now nearly obsolete. The separator (Fig. 113) is a centrifugal machine designed for continuous flow; many sizes are manufactured, capable of dealing with from 10 to 900 gallons of milk per hour. The milk is allowed to run into a perfectly balanced bowl rotating at about 6,500 revolutions per minute, which contains a number of discs super-imposed upon one another so that the liquid is centrifuged in thin layers, thus increasing the separating capacity of the machine and reducing the speed necessary. During separation the cream passes to the centre of the bowl and emerges to the outlet pipe through an adjustable "cream screw" which controls the richness and thickness of the cream produced. The separated milk passes to the outside of the discs and flows away through a separate pipe. After all the milk has been separated, a little separated milk should be returned to the bowl to flush out the cream which remains therein. Milk should be separated at not less than 90° F., immediately after being drawn from the cow, and the separator should be set up on a firm, level foundation. Once the cream screw has been fixed satisfactorily it should not be re-adjusted without due deliberation.

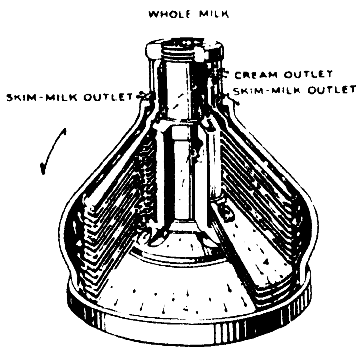

FIG. 114.—ALFA-LAVAL SEPARATOR BOWL.

CREAM which is intended for table consumption should always possess a fluid consistency as cream which is very rich in fat frequently becomes a thick paste which cannot be poured. In Britain there are two types of cream sold, "thin cream" containing 25 to 30 per cent. of butter-fat, and "double cream" containing 50 to 55 per cent. of butter-fat and about 4·6 per cent. of non-fatty solids. Cream which is to be used for whipping should contain at least 43 per cent. of butter-fat, although if very cool and under favourable conditions that containing as little as 35 per cent. may whip satisfactorily.

Cream which is intended for butter-making is first "ripened" with a culture of lactic acid bacteria, known technically as a "starter." Starters are of two kinds, namely home-made or natural

starter, which is merely soured milk or skim milk containing wild strains of organisms and consequently often grossly impure, and starters propagated from pure bacterial cultures. The latter are now used extensively.

Butter.—The intensity and character of the flavour and aroma of good butter depend upon the treatment of the cream. The most uniform butter is made from cream 24 to 48 hours old, churned sweet or ripened by means of a starter ; it is impossible to secure uniformly good butter throughout the year from badly ripened or poor flavoured cream. On the farm churning should take place two or three times weekly. A third of a pint of starter is added to each gallon of cream placed in the ripening vat ; the mixture should be well stirred and allowed to stand at 65° to 68° F. As each batch of freshly separated cream is obtained, it is added to the bulk at the correct temperature and well stirred in. Fresh cream should never be added to that which is already ripened within twelve hours of churning since this practice results in loss of butter-fat in the butter-milk. In some dairies the cream is pasteurized by heating to 145° F. for 30 minutes, or to 180° F., followed by prompt cooling to 68° F. in both cases ; pasteurization prior to ripening ensures greater uniformity by destroying much of the miscellaneous germ life in the cream.

The operation of churning results in the destruction of the "fat in skim milk" emulsion of the cream as indicated by the coalescence of the globules of fat into particles as large as wheat grains. The residual liquid after churning is finished is known as butter-milk. The best results are obtained with cream containing about 30 per cent. of butter-fat and a titratable acidity of 0·30 per cent., that is, when the cream tastes and smells decidedly sour, although it should have a pleasant flavour and be thick and smooth in appearance ; churning should take place at 55° to 58° F. in summer and 58° to 63° F. in winter. The texture of butter is ruined in many cases by churning at too high a temperature, or by churning the butter into a lump, or not working it sufficiently on the worker. Streakiness or discolouration may be caused by churning the butter too far, which impedes the washing out of the butter-milk and reduces the keeping qualities.

The churn should be rotated at 40 to 60 revolutions per minute, according to the type used, and should be ventilated freely during churning. If the cream "goes to sleep" after churning for 25 to 30 minutes the lid and sides of the churn should be rinsed with cold water and butter will usually come with a few more revolutions of the churn.

Churning should cease as soon as butter comes, when the temperature of the butter and butter-milk should be taken, so that during the subsequent washing and brining processes the butter may keep its grain and not get into a lump. A small quantity of "breaking water" is first added 5° F. lower than the churning temperature to cool the butter and separate the grains ; churning

is then continued until the butter is the size of small wheat grains. The butter-milk should be drawn off and the butter washed once with cool water if brining is practised and twice if dry salting is relied on. When salting with brine, the butter should be covered with brine made at the rate of from 1 to 2 lb. salt per gallon of water, and the churn rotated six or eight times and then left for a quarter of an hour.

WORKING THE BUTTER.—The brine should then be drawn off and the grains of butter transferred by a hair sieve to the " butter-worker " where they are allowed to drain for a short time before the excess of moisture is removed by the roller. Frequently the brining of butter is replaced by drysalting, when from ½ to ¾ oz. of salt is

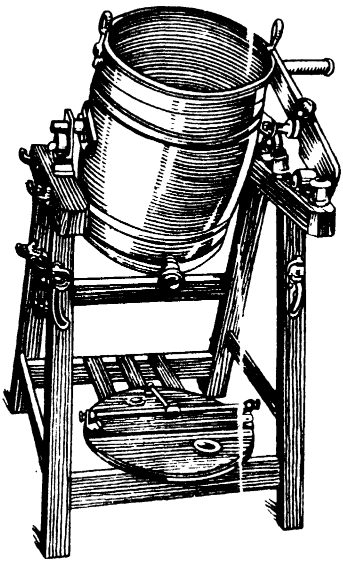

FIG. 115.—CHURN.

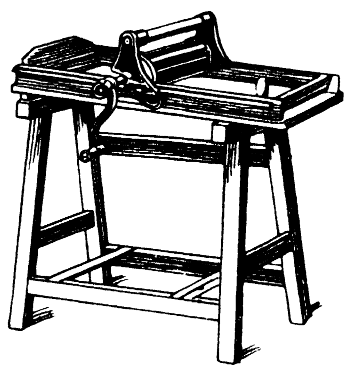

FIG. 116.—BUTTER-WORKER.

added to each pound of butter during the working operations, and the butter is left on the worker for about an hour, covered with muslin, before it is worked dry, to make sure that the salt dissolves and so prevents the development of a streaky, mottled appearance. Superfluous moisture from butter may be removed by the " délaiteuse " which is a centrifugal drying machine capable of being rotated at about 750 revolutions per minute. The butter is finally weighed into pounds and half-pounds and moulded with a pair of " scotch hands " to obviate handling. To comply with the Food and Drugs (Adulteration) Act, 1928, butter should not contain more than 16 per cent. moisture.

CLEANING THE CHURN.—When butter-making is finished, the churn and other utensils should first be rinsed with water at 125° F.

to remove the grease, then scrubbed with hot water, and finally scalded with boiling water and left to dry.

Qualities of Good Butter.—Well-made butter should be firm in texture and not greasy, and should cut clean with a knife and break with a granular fracture. Cotton cake, coconut-cake and bean meal tend to produce a hard, white butter, while linseed cake, rice meal and young grass tend to make butter soft and greasy; carrots, parsnips, fresh grass, silage and green fodder crops impart a pleasing yellow tint to milk fat and butter. The amount of butter obtained from milk depends upon the fat content of that milk. In the case of Jersey and Guernsey cattle one pound of butter may be obtained from two gallons of milk, but three gallons may be required from Friesian or Red Poll cows. The ratio of the number of pounds of milk necessary to give one pound of butter is known as the "butter ratio."

Cheese.—In cheese-making the aim is to collect the casein with all or as much fat as possible, evenly distributed throughout the whole mass; thus the main food constituents of milk are converted from a bulky and quickly perishable state to a condition in which they may be easily transported or stored for a considerable period.

The process of modern cheese-making depends upon the ability of an enzyme or ferment, which is prepared from the stomachs of young calves and known as "rennet," to convert milk into a white solid and a greenish liquid. The solid material is called "curd" and contains the casein and almost all of the milk fat, whereas the liquid, which is known as "whey," contains practically all the milk sugar and albumen of the milk.

In the manufacture of cheese the curd is gradually reduced to the correct consistency and finally moulded to a suitable size and shape for ripening and storing. It is essential that the cheese-maker should be able to control properly the acidity and moisture content of the curd, since a correct balance between these factors must be maintained at all stages for the variety of cheese manufactured. Acidity is developed either by encouraging the lactic acid-producing types of bacteria normally found in milk, or by the addition of a culture of starter; the control of the degree of acidity produced is affected largely by temperature.

The agents utilized in cheese-making for drying the curd are acidity, rennet, cutting of the curd and scalding. It is by slight modification in the application of these agents that different varieties of cheese are made.

Varieties of cheese are divided into three general groups, "hard-pressed," "blue-veined" and "soft cheese." Hard-pressed varieties comprise Cheddar, Cheshire, Derby, Lancashire and Caerphilly; blue-veined types include Stilton, Wensleydale, Dorset Blue and Gorgonzola, while Camembert, Pont l'Evêque, Coulommier, Brie and cream cheese are instances of varieties of soft cheese.

Cheddar Cheese originated in Somerset and is named after the village of Cheddar which has long been celebrated for its cliffs and caves. Travellers would often partake of cheese which came to be called by the name of the village, but its manufacture in the actual neighbourhood of Cheddar is of comparative recent date, and it is now manufactured on farms and in cheese factories in many countries of the world. It is probably the most popular of the British hard-pressed varieties.

The cheese is made from whole milk and the morning's milk is mixed with that produced the previous evening. It is essential to use milk produced under clean conditions in order to avoid the development of undesirable flavours and taints which may result from the action of the types of bacteria common in dirty milk. When this cheese is made in factories from milk collected from many farms it is a common practice to pasteurize the milk and then develop the necessary acidity by the addition of a starter. The mode of

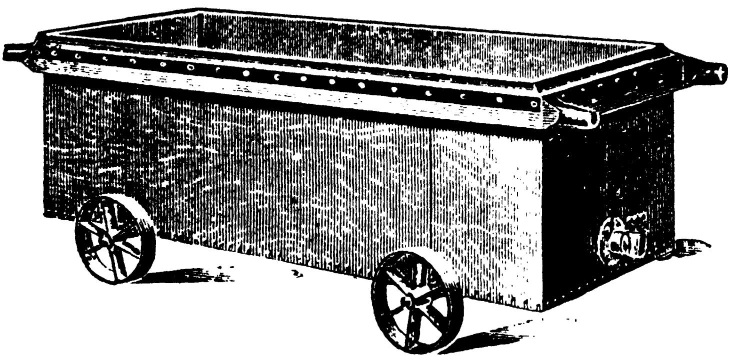

Fig. 117.—Cheese Vat.

manufacture of Cheddar cheese varies considerably in different districts and with different types of milk, and while the following details give one method as an example it should be realized that any times and figures given can only be approximations which may need to be varied within quite wide limits.

The milk is placed in a jacketed vat in which the temperature can be controlled by water and steam admitted to the outer jacket. Acidity is developed until it is about 0·06 per cent. higher than that of the milk originally; this usually gives an acidity of about 0·22 per cent. by the acidimeter test, and the temperature is then maintained at about 85° F. Rennet is added in sufficient quantity to curdle the milk and bring the curd to such a firm condition that it will break cleanly over the finger after 40 to 50 minutes. The curd is then cut with special knives (Fig. 118) to about the size of peas; this liberates moisture, and the smaller the curd is cut, the more quickly it dries. After cutting, the curd is gently stirred and the temperature gradually raised to about 100° F.; this "scalding" is

a further drying agent and the temperature and time occupied varies considerably. The process is continued until sufficient firmness has been obtained in the curd. The average time required for scalding is about one hour from the time of cutting. The curd is then allowed to settle in the whey, which is drawn off when its acidity reaches about 0·17 to 0·18 per cent. The curd will now consolidate into a mass which is cut in squares of about 9 in. for convenient handling. Acidity should be developing in the curd at a fairly rapid rate, and turning and piling the curd is normally carried out at intervals of about 20 minutes in order to obtain the necessary dryness. The curd is ready for grinding when a rubbery texture has developed and the acidity of the whey has reached about 0·8 per cent. ; the time taken to reach this stage may be about three hours from the time of drawing the whey. The curd is ground in a mill, salted at the rate of about 1 oz. of salt to 3½ lb. of curd,

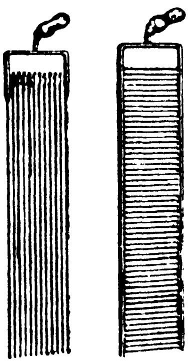

FIG. 118.—CURD KNIVES.

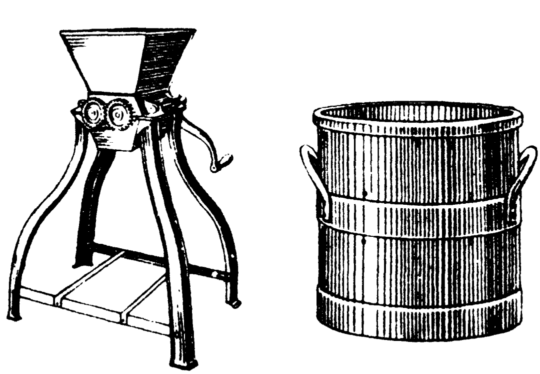

FIG. 119.—CURD MILL AND CHEESE MOULD (RIGHT). NOT TO SCALE.

and placed in moulds for pressing. The size of the moulds varies ; the larger cheeses usually weigh 60 to 80 lb. and the smaller or "truckle Cheddar" cheeses weigh 12 to 14 lb. After pressing for about two days the cheese is bandaged and placed in a ripening room where it is turned over daily. It should be ready for consumption in four to eight months.

CHESHIRE CHEESE.—This hard-pressed cheese is named from the county of its origin and, in common with Cheddar, it is an extremely popular variety.

The manufacture is somewhat similar to that of Cheddar but the finished product is milder, more open in texture, and often coloured by the use of annatto colouring.

Clean, whole milk is used and the details of making vary according to whether a rapid, medium or slow ripening cheese is desired.

Up to the time of moulding, the chief difference between Cheddar and Cheshire cheese-making is that at all stages the latter is kept

less acid and more moist ; thus the following acidities are commonly used for Cheshire cheese-making : rennetting at 0·18 per cent., whey drawing at 0·15 per cent. and grinding at 0·45 per cent. At the same time, the moisture content is kept higher by cutting the curd into larger pieces and scalding at a lower temperature, *e.g.*, 92° F. After placing in the moulds Cheshire cheese is not pressed for about 24 hours, and during the period it is kept in a warm room at about 75° F. This treatment encourages the development of acidity at a later stage than in the case of Cheddar and results in a much more open textured cheese. Ultimately, pressing, bandaging and ripening are carried out as with Cheddar, and the cheese should be ready for consumption in two or three months, but will keep much longer if desired.

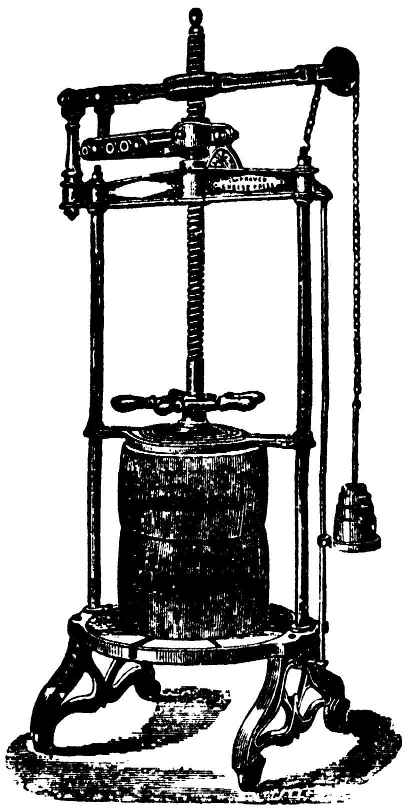

FIG. 120.—CHEESE PRESS.

BLUE-VEINED CHEESE.—The best-known example is Stilton cheese, which is familiar to every English-speaking race. Stilton cheese-making probably calls for more skill and attention to detail than any other British variety. Blue-veined cheeses are not ground and pressed like hard-pressed cheeses as the aim is to retain an open texture so that the characteristic blue mould, known as *Penicillium glaucum*, may develop in veins during ripening.

Although the manufacture of Dorset blue cheese has now almost entirely died out, it is interesting to note how it fitted into the prevailing system of dairy husbandry and provided a means of utilizing the skim milk. Before cream separators came into general use the skim milk obtained by the shallow pan method still contained 0·5 to 1·0 per cent. of butter-fat ; the method of manufacture was to convert the skim milk into a satisfactory cheese by working with high acidities and moisture content. With mechanically separated milk the resulting cheese is hard and unsatisfactory. This system of cheese-making fitted in well with butter-making or cream-selling.

SOFT CHEESE.—The home of the manufacture of soft cheeses is

France, but they can be made satisfactorily in Britain. Soft cheeses are not subjected to heat or pressure in any stage of manufacture, and as a result of the natural drainage a high moisture content is normal. Most soft cheeses deteriorate rapidly after maturity has been reached, and much care is required in the manufacturing and ripening conditions if first-class results are to be obtained. In general, three rooms are necessary—(1) a " making room " in which the milk is coagulated, drained and moulded ; this room need not be large but should be provided with a means of artificial heating ; (2) a " drying room " where the cheeses undergo the earlier stages of ripening and which should be subject to easy control of ventilation and temperature ; (3) a " ripening room " or " cellar " where ripening should be completed under cool, moist conditions.

Coulommier Cheese.—To 2 gallons of milk add 12 drops of rennet and set at 84° to 87° F. ; stir for 3 minutes and then at intervals during the next 2 hours until coagulation commences to prevent the cream from rising. In 6 to 8 hours the curd will be ready to be ladled out in thin slices into circular moulds which are placed on scalded straw mats to assist drainage. The moulds are $5\frac{3}{4}$ in. deep and 5 in. in diameter (Fig. 121). On the following day the upper part of the mould should be removed, the cheese turned on to a fresh mat and the surface sprinkled with salt, while later in the same day the cheese should be turned again and the other side sprinkled with salt. The cheese must be turned every day until ready for use. In Britain, Coulommier cheese is not ripened but eaten fresh from three to six days after manufacture. Half a gallon of milk is required for each cheese.

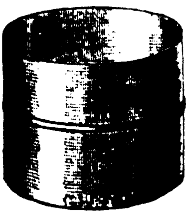

Fig. 121.—Coulommier Cheese Mould.

Cream Cheese.—Two varieties are made, double-cream cheese, from sweet cream containing about 50 per cent. fat, and single-cream cheese from thin cream which is ripened with starter and thickened with rennet before drainage takes place.

Double-Cream Cheese.—Take half a gallon of freshly separated thick cream and add one pint of warm milk to bring the temperature up to 80° or 84° F. ; add 2 cc. of rennet and stir well for one minute. After an hour cut the thickened cream into squares, ladle carefully into two fine textured linen cloths and remove to a cool place to reduce the temperature as much as possible. After another hour the cloths containing the cream should be hung up to enable the whey to drain away ; the inside of the cloths should be scraped three or four times during the day to facilitate percolation. If the cream cheese is not firm enough to mould the next morning slight pressure should be applied. Before placing in moulds salt should be added at the rate of half an ounce for each half gallon of cream used.

During periods of hot weather the salt should be added at an early stage to accelerate drainage.

Instead of hanging the cream cheese cloths they are sometimes drained by placing them in shallow boxes of white sycamore wood provided with bottoms of laths; when pressure is to be applied, a well-fitting lid is placed over the cloths and a suitable weight laid thereon.

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CHAPTER XXVII.

ANIMAL HYGIENE.

Farm animals, like all living creatures, are at times the subjects of accidents and diseases of various kinds which occasion a certain amount of suffering and some pecuniary loss to the owner and to the state. These unfortunate accompaniments of animal husbandry will continue in spite of the most elaborate precautions, but it cannot be too strongly emphasized that the effects of their incidence can often be reduced to an almost negligible significance by the application of simple preventive measures. Even in the case of the great animal plagues which, fortunately, are of rare occurrence in this country, a reasonable knowledge of animal hygiene will go far to prevent their ingress to a particular herd or flock, and to limit their ravages.

In thus striving to avoid suffering and wastage among animals the efforts of the farmer himself play the most important rôle, and while it would obviously be unreasonable to expect him to acquire a profound knowledge of all the ailments to which they are liable, he should, in his own interests and in those of others, be acquainted with the main features of the common contagious diseases and with the broad principles of animal hygiene. The early recognition of abnormal conditions and the equally early establishment of methods for their control are of the utmost importance.

In the case of non-infectious diseases and of common accidents a sound knowledge of the principles of first-aid methods of treatment is often the means of saving valuable lives and of preventing wastage and suffering. It is no less important to realize our limitations in this direction and to seek professional assistance in all cases of doubt, for many apparently mild ailments, unless properly treated, may

lead to serious complications, while others may be the symptoms or forerunners of some much more dangerous complaint.

In the following pages an attempt has been made to deal briefly with the care and attention which should be devoted to sick animals and with first-aid treatment : the later part outlines the features of the more important contagious diseases with special reference to their prevention and control.

THE CARE OF SICK ANIMALS.

SIGNS OF DISEASE.—The average owner is well acquainted with the appearance of animals in health and readily notices any obvious departures from the normal, *e.g.*, loss of appetite, listlessness, dullness of the eye and of the coat, injection of the superficial blood vessels and so on : these changes are of great significance and should be carefully noted. In addition, the veterinarian will often require additional information on such matters as the number of animals affected, change of habits, quantity of food and water taken, appearance of constipation or diarrhœa and the character of the dung and the urine, as well as the nature of any secretions.

ISOLATION BOX.—Provision should be made for a sick box not only for the comfort of the sick animal, but also because the prompt isolation of an animal which is obviously unfit and may be in the early stage of an infectious disease, will often check an incipient outbreak. This loose-box should be situated as distant from the healthy stock as is practicable and should be roomy, well-ventilated and easily disinfected ; it should also contain a minimum of fittings which, with advantage, should be of the movable type. The care of the sick animal ought to be entrusted to one person ; if it is not possible for this attendant to devote the whole of his time to the invalid and he is obliged to mix with the healthy stock, he should attend to them before proceeding to the sick quarters, and should also thoroughly disinfect his hands and his clothing before returning to the uninfected animals. The most scrupulous care must be exercised in maintaining the cleanliness of the sick quarters and in their thorough and regular disinfection. The best type of bedding is wheat straw which should be frequently renewed, the old bedding being destroyed. The importance of fresh air cannot be over estimated although, unfortunately, an opinion is still widely held that the exclusion of air by stopping up the windows and doors is essential for the recovery of the sick animal. It cannot be too strongly urged that the provision of an ample supply of fresh air, without necessarily allowing draughts, is of very material aid in all diseases, particularly in those of the respiratory organs. Even in the most severe weather, the upper half of the door may be left open, the bodily heat being maintained by light rugs, bandages to the legs and an abundance of bedding, a procedure which has the further advantage that the benefits of the sun's rays are not lost.

FOOD AND WATER.—*A plentiful supply of clean water, preferably with the chill taken off, should be available at all times. The choice of a diet is also of great importance, for in most illnesses and more especially in those which are accompanied by a high temperature, the appetite is in abeyance, and a variety of palatable and easily* digested foods should be offered in order to tempt the animal. In *most diseases, a slightly laxative diet is desirable in order to promote* a free movement of the bowels and thus aid the elimination of toxic products. A description of the more important diets, which are usually recommended as suitable, may here be given together with their methods of preparation.

Bran mash.—Place 3 lb. of bran in a clean pail with a little water and scald for half an hour ; then add 3 pints of boiling water and a pinch of salt, cover, and allow to cool to a suitable temperature. If a more laxative diet is required, a bran and linseed mash may be prepared by boiling together for two to three hours, 1 lb. of linseed and 2 lb. of bran in 1 gallon of water. With regard to mashes containing linseed, it is important either to boil the linseed or at least to ensure that the water which is used is actually boiling ; failure to observe this precaution is not infrequently responsible for cases of poisoning in live stock by hydrocyanic acid which may be liberated when linseed is allowed to ferment. Linseed tea is a useful demulcent prepared by boiling ½ lb. of linseed in a gallon of water for several hours and straining. Hay tea is made by filling a bucket with good hay and scalding with boiling water ; the mixture is covered and strained when cool. Gruel is prepared by making into a thin paste with water, 1 lb. of barley or oatmeal and heating with continuous stirring ; it should not be too thin in consistency. In cases of great exhaustion or collapse, especially for a valuable animal, it may be necessary to administer eggs beaten up in milk with or without a stimulant, such as a little whisky. The value of green foods, *e.g.*, clover, lucerne, rye grass, carrots, etc., in tempting the fickle appetite must not be overlooked.

TEMPERATURE.—The various infectious diseases are usually accompanied by a definite rise in temperature which is often in existence before the appearance of visible lesions. A febrile condition can be recognized by certain external signs such as shivering and rigours, accompanied by great depression ; the breathing is rapid, the pulse bounding and there is great thirst and loss of appetite. The rise in temperature can be registered by means of a clinical thermometer which, in the domesticated animals, is usually inserted into the rectum. In taking the temperature, it is important to first shake down the column of mercury for failure to observe this precaution may result in a false reading ; in addition, it is advisable to adhere to the stated time (30 secs., 1 min., 2 min.) which is marked on all reliable instruments. The temperature of the adult animals of the farm in health may be

taken as : Horse 100°—101° F., Cow 101°—102° F., Sheep 103°—104° F., Pig 102°—103° F., Fowl 105°—107° F. In young animals the normal temperature is slightly higher.

ADMINISTRATION OF MEDICINES.—During the course of an illness, it is often necessary to administer medicines either in a solid or a liquid form, a simple matter provided reasonable care is taken particularly in the case of liquid preparations. In the horse, many drugs are given in the form of a ball. The animal is haltered and turned round in the stall, the bolus is taken between the fingers of the right hand, the tongue is pulled forward and the tip turned upwards by the left hand. The right hand is then quietly passed over the tongue to the back of the throat, the ball released and the hand withdrawn : no difficulty need be experienced provided the operation is carried out without undue fuss. The left side of the neck should be watched so that the descent of the ball through the gullet can be seen, for some animals will retain the bolus in the back of the throat and then reject it after several minutes. In giving a draught to a horse, the bottle, which should have a long and narrow neck, is introduced by one hand between the jaws through the space anterior to the molar teeth, the chin being elevated by the other hand. The drench must be given slowly with frequent pauses, and care must be taken not to hold the chin too high or the animal may be choked. It is inadvisable to give fluid preparations to an animal which is suffering from an acute disease of the respiratory organs. In sheep and cattle, the bottle can be passed between the front of the jaws—otherwise the same precautions should be observed as in the case of the horse. It is often convenient to administer drugs in the food especially when an exact dose is not of great importance : some of the remedial preparations which are of value against the various internal parasites of the horse, the calf, the sheep and the pig may, with advantage, be given in this manner.

CONVALESCENCE.—During the period of convalescence from a febrile complaint the power of undertaking heavy work is severely limited, and the amount of exercise which is allowed should be strictly graduated. It is wise to progress slowly for undue haste in returning an animal to full work may lead to a sudden relapse. The benefit of exercise in a lame animal varies according to the cause of the lameness, and the advice of the professional attendant should be closely followed.

FIRST AID MEASURES.

MEDICINE CHEST.—It is a wise precaution to maintain in a readily accessible place an emergency chest which should contain the following articles : several lengths of bandage of tarlatan or calico, medicated lint, antiseptic cotton wool, tincture of iodine (2½ per cent.) or other suitable antiseptic lotion, a clinical thermometer, linseed oil and turpentine, etc.

HÆMORRHAGE.—The occurrence of severe bleeding as the result of an accident or as a sequel to an operation, may necessitate prompt measures in order to save an animal from bleeding to death, although there is a natural tendency towards the arrest of hæmorrhage by the process of coagulation, which is usually sufficient to check the flow of blood. Uncontrollable hæmorrhage may take place from a severed artery or vein, or from an extensive wound : arterial blood, which is thrown out in jets, can be recognized by its bright red colour, whilst venous blood flows quietly and is dark in colour. If a large blood vessel of ' limb is severed, the bleeding may be arrested by a tourniquet which can be improvised from a piece of rope or a handkerchief twisted by a piece of stick and placed above the wound in the case of an injured artery, *i.e.*, nearer the heart, and below the injury in the case of a vein. As a rule it will be necessary to seek advice in order that the severed ends of the vessels may be ligatured. Large superficial wounds may be plugged with cotton wool, preferably sterile, held in position by a bandage. In persistent hæmorrhage it is essential to keep the animal as quiet as possible, since movement tends to increase the danger. Cold water is a valuable styptic and may be freely used in such injuries as hæmorrhage following castration, which is sometimes rather troublesome ; in bleeding from the nostril and so on. A rupture of an internal vessel is an unfortunate accident for which little can be done, beyond keeping the animal quiet. In cattle fractures of the horn core are frequently followed by excessive hæmorrhage ; the core should be carefully replaced and held in position by a figure of eight bandage round the base of both horns.

FRACTURES.—It is a common belief that fractured bones in the larger animals will not unite, but this view is quite erroneous for, if the broken ends are brought into proper apposition, a satisfactory union will take place. In the larger animals, however, the treatment of a fractured limb is a lengthy and difficult process, and is rarely an economical proposition. Fractures may be simple or compound ; in simple fractures, there is a clean break in the bone without splintering or injury to the skin, whilst in compound fractures, the broken end of the bone penetrates the skin. This complication is always serious, for it paves the way for the entrance of various micro-organisms which may set up a suppurative condition and thus considerably retard the process of healing. A fracture of a limb can be detected by the shortening which generally occurs, and by the inability to carry weight on the injured member. By careful manipulation the broken ends, when rubbed together, will give a characteristic sound known as "crepitus," but great caution must be exercised in applying this test or a simple fracture may be converted into one of the compound type. In a case of fracture, the first step is to restrain all movement as far as possible. If a bone of a limb is broken, the damaged member may be supported by light, flat pieces of thin wood placed, one on the outer face and one on the inner face of the limb, and kept in position by light

bandages; these supports should be well wrapped in a soft material, such as cotton wool, in order to avoid undue pressure. In uncomplicated cases after four to six weeks the union between the fractured ends of the bone should be sufficiently strong to enable the animal to put some weight on the limb.

WOUNDS AND INJURIES.—Although wounds of various kinds are amongst the commonest accidents which befall live stock, it is to be feared that sufficient attention to their proper treatment is rarely taken by the average attendant. In the horse, the most frequent injuries are bruises resulting from falls, injuries to the knees, fetlocks, etc., and injuries to the feet through picked up nails or other sharp objects. In the hunting field, extensive lacerations from barbed wire, penetrating wounds from stakes or kicks from other horses may necessitate prompt first-aid treatment. In cattle, severe lacerating or penetrating wounds arise from the horns of other animals. In the treatment of wounds, thorough cleanliness is essential in order to check the invasion of micro-organisms which not only retard healing, but are also liable to leave ugly blemishes. After the hair has been carefully clipped around the edge of the wound and foreign particles such as fragments of hair and splinters of wood, etc., have been removed, the wound may be cleaned with cold water, and a mild antiseptic lotion applied. Cold water from a hose is of great value in checking hæmorrhage and as a cleansing agent; on the other hand, the bathing of a wound with warm water is to be discouraged, for the entrance of micro-organisms is thereby greatly facilitated. Great care must be exercised in the choice of an antiseptic lotion, for strong solutions are likely to cause more harm than good by destroying the living cells around the wound: as a general antiseptic, weak tincture of iodine (1 per cent. to 2½ per cent.) can be recommended and if this is applied to a wound in the first instance, it will frequently be found that no further treatment will be necessary. Injuries to the lips, the mouth, the nostril and the tongue heal without much difficulty: on the other hand, punctured wounds are much to be feared not only on account of troublesome hæmorrhage, but because they are often followed by dangerous sequelæ such as abscess formation, tetanus, etc. Discharging wounds require frequent attention for, unless the edges of the injury are kept clean, the excretion will dry on the hair forming a hard mass which not only retards healing but also attracts flies. During treatment the animal must be prevented, as far as possible, from licking the wound. As a rule, the treatment of simple superficial injuries can be undertaken by the owner, but extensive wounds may require suturing in order to hasten healing and to avoid unsightly scar formation. A rise in temperature must be regarded with grave suspicion as it usually indicates a serious bacterial invasion of the body from the wounds.

During the process of healing it is sometimes advisable to protect the injury by bandages, but, whenever possible, these should be avoided for, unless the wound is quite clean, free drainage must

be encouraged. The most suitable bandages are made of soft material, e.g., calico, tarlatan; they must not be applied directly to the wound, but separated from it by a layer of medicated lint or a cotton wool pad. In wounds of the limb it is important to guard against restriction of the circulation by an excessively tight bandage.

INJURIES TO THE EYE.—The presence of a foreign body in the eye is a frequent and troublesome condition which demands immediate attention. This accident may be suspected when an animal shows a congestion of the conjunctiva and a running of tears, together with a tendency to keep the lids closed. The main line of treatment in these cases should be directed towards allaying the intense irritation which is always present; to this end, the animal should be secured and a few drops of olive oil or a weak solution of warm boracic acid dropped on to the eyeball by means of a clean fountain-pen filler. The eye may then be searched for the offending body by twisting the head so that a good light falls on the eye, the eyelids being held apart by an assistant. If the object is of the nature of a piece of chaff, particle of dirt, etc., it may be gently dislodged by a camel hair brush; if, on the other hand, a sharp body has become embedded in the cornea, it may require removal by a pair of fine forceps, but this operation should not be attempted by an amateur as the cornea is very delicate and easily injured. During the period of inflammation, the animal may, with advantage, be kept in a darkened stable.

ABSCESS FORMATION.—Acute abscesses result from the bacterial invasion of the tissues either through a wound, or through the penetration of the skin by a foreign body: these organisms multiply in the tissues forming toxic products which are destructive to the cells. The body tissues, in their turn, react to the irritant by extruding from the blood the so-called "white cells" or phagocytes, which engage in battle with the bacterial invaders: the pus is produced from broken down cells, dead bacteria and the exudate from the blood vessels. If the abscess is situated near a surface, it will finally break through and thus liberate its contents. In the treatment of abscesses, "pointing" should be encouraged by the application of hot fomentations. As soon as signs of softening are evident, and not before, it may be advisable to open the swelling and to evacuate its contents. The incision should be bold and should extend to the lowest point of the fluctuation in order to ensure adequate drainage, but great care must be taken to avoid injury to blood vessels, nerves, joints, etc. Chronic abscesses are frequently encountered in such diseases as Tuberculosis and Actinomycosis.

CHOKING is a comparatively common accident, especially in the ruminant species in whom it frequently arises through the obstruction of the gullet by a piece of a root or other similar object. The chief symptoms, which may be expected, are a cessation of feeding, possibly a persistent cough and signs of distress as evidenced by

arching of the neck and spasms of the neck muscles ; the mouth is kept partly open and in a few minutes there is an abundant flow of saliva. In the ruminant animal, choking is a serious condition on account of the liability to tympany (see Hoven), and prompt measures may be required in order to save the life of the animal. The beast should be secured and an attempt made to dislodge the obstruction by passing the hand to the back of the throat if the object is fixed in the pharynx or, if it can be seen as a swelling on the left side of the neck, by a gentle manipulation of the gullet. If these efforts fail, the animal should be offered a drink of water, and a gag inserted in the mouth to facilitate the eructation of the gases imprisoned in the rumen : in any case, no time should be lost in seeking professional advice. Under no circumstances should an attempt be made to remove the obstruction by an instrument on account of the danger of rupturing the œsophagus. In acute cases of tympany, it may be necessary to puncture the rumen in order to allow the accumulated gases to escape.

HOVEN or Tympanitis of the rumen is an acute form of indigestion in which there is a distension of the rumen by gases. As already mentioned, it not infrequently arises secondarily to choking, but it may also result from the feeding of excessive quantities of readily fermentable foodstuffs. The condition may become extremely dangerous for if relief is not promptly afforded the animal is likely to die from asphyxia. Whilst awaiting the veterinary surgeon, a pint of linseed oil may be given and the measures advocated for choking may also be applied.

ARTIFICIAL RESPIRATION may be required in cases of drowning and poisoning, and in animals which have been overcome by noxious fumes or have been choked, although occasions for the application of these measures arise less frequently in the lower animals than in the human subject. The animal should be brought into the open air and all restraint should be released : then, whilst an assistant extends the head and pulls forward the tongue, the operator alternately presses and releases the posterior ribs with the hands or the foot once every four to five seconds. After a few minutes, the animal is rolled on to the other side and the process repeated ; meanwhile, the circulation may be stimulated by flicking the body with wet towels. Hope need not be relinquished so long as the heart beats can be felt.

POISONS.—Cases of accidental or malicious poisoning of farm animals, both large and small, may demand immediate attention by the owner of the affected stock, who should have a general idea of the common poisons and their antidotal treatment. Cases of poisoning by minerals, due to the ingestion of preparations containing lead, arsenic, phosphorus, etc., are not infrequent, and usually arise from the careless disposal of sheep-dips, paint pots, disinfectants, weed-killer, rat poisons, etc. ; more common, perhaps are outbreaks of poisoning by plants either in the fresh or dried

state. Amongst the latter there are included certain toxic seeds which are sometimes incorporated in compound cakes, and in samples of grain of foreign origin.

The symptoms of acute poisoning are often alarming and call for prompt measures in order to save the lives of the affected animals. In the first place immediate steps must be taken to ascertain, if possible, the origin and nature of the poison and to prevent further access to it; then the stomach contents should be evacuated by means of an emetic, *e.g.*, salt and mustard and water, and the effects of the poison counteracted by means of a suitable antidote. Demulcent fluids, such as thin oatmeal gruel or barley water, are of value except in the case of phosphorus poisoning. The following is a list of a few of the common poisons with their appropriate antidotes :—

POISON.	ANTIDOTE.
Mineral acids.	Bicarbonate of soda or magnesia.
Oxalates (salts of lemon).	Magnesia or lime water.
Caustic soda or ammonia.	Vinegar.
Carbolic acid.	Glauber salts or turpentine.
Lead.	Epsom salts or dilute sulphuric acid.
Arsenic.	White of egg.
Mercury.	Epsom salts or olive oil.
Phosphorus.	Charcoal or sulphate of copper.
Belladonna.	Stimulants such as coffee.
Foxglove.	Stimulants.
Hemlock.	Stimulants.
Strychnine.	Sedatives such as Chlorodyne or Chloroform.

THE NATURE OF INFECTIOUS DISEASES.

Infectious diseases are caused by micro-organisms which are transmitted from affected to healthy animals in a variety of ways : in some cases, the infecting agent is readily passed from one animal to another, *e.g.*, in foot and mouth disease, whilst in others, the methods of spread are less obvious. In many cases, direct contact between infective and healthy animals appears to be a necessary factor in the maintenance of diseased conditions, but it must not be forgotten that transmission by indirect means plays an even greater part in the dissemination of many diseases, for the various excretions and secretions are often highly infective and by contaminating foodstuffs, water, clothing of attendants, etc., may be the means of setting up outbreaks at distant points. Some diseases are spread by the wind, and others by biting insects. In general, the contagious diseases are caused by specific micro-organisms : some of these normally maintain their existence in the animal body and have but limited powers of multiplication or survival outside the body, whilst others are capable of an independent existence in soil, manure, etc.

IMMUNITY.—The cells of the body possess certain powers of resistance whereby they are enabled, more or less successfully, to prevent the invasion of these attacking organisms. If, on

account of the numbers or the virulence of these bacteria, or through the enfeeblement of the body, this defensive mechanism is overcome, the animal is said to have become infected ; as a result, it may either succumb to the invading organism, or it may recover from the disease in which case it is successful in overcoming the bacteria, after a more or less protracted illness. As a general rule, when an animal has passed through an attack of this nature, it possesses a certain degree of resistance against re-infection ; it is said to have acquired an "active immunity."

In some instances it is possible to induce an artificial immunity of the active type by the inoculation of an appropriate vaccine, *e.g.*, anthrax, black quarter, and thus protect the animal against the disease in question. This active immunity depends upon the presence in the animal body of certain protective substances termed "antibodies" which are manufactured by the animal itself and are often present in the blood serum. The injection of this serum into another animal will produce a "passive immunity" due to the transference of antibodies from the first animal, and the use of such sera in conferring a passive immunity is of value in certain diseases, *e.g.*, tetanus, swine erysipelas.

CONTAGIOUS DISEASES.

ANTHRAX.—Anthrax is an acute infection of the horse, ox, sheep and pig caused by a specific organism (*Bacillus anthracis*), and can arise from no other source. The disease is set up by the spores of this organism, either through the ingestion of contaminated foodstuffs or water, or through abrasions of the skin ; these spores are extremely resistant and may remain fully infective outside the animal body for many years. In certain localities, where the soil has become contaminated with anthrax spores, the disease appears at regular intervals, but, in addition to this source of infection, the importation from foreign countries of infected hides or other animal products, and of artificial foods (linseed cake, etc.) is a not infrequent cause of many outbreaks in this country. The disease is almost invariably fatal, death occuring with great suddenness especially in cattle and sheep, and in many animals no antecedent evidence of illness may be noticed. For this reason, cases of abrupt death amongst farm stock should be regarded with the utmost suspicion, and, unless the cause of the death is very evident, no attempt should be made to move or to cut the carcass in any way until professional advice has been sought. In the unopened carcass, the anthrax bacillus is rapidly destroyed by putrefactive changes, but the free access of oxygen, which follows the opening of the body, permits the organisms to assume the resistant sporulating form ; it is therefore of paramount importance that the carcass should not be mutilated in any manner. Shed blood is a particular source of danger and should be carefully collected and destroyed ; moreover, great care should be exercised in the handling of anthrax carcasses since

man is susceptible to infection. In districts where continued losses from anthrax are experienced, the protection of susceptible animals by means of a preventive inoculation is often of value.

Anthrax is a scheduled disease and any person having a diseased or suspected animal must notify the Local Authority of the fact. It is incumbent on the owner to prevent the access of animals to a suspected carcass, or to premises which have been exposed to infection; in addition, infected buildings, fields, etc., must be disinfected as soon as possible, and no animal, litter or fodder may be moved without permission of the Inspector of the Local Authority. The carcass must be disposed of by the Local Authorities either by burning or, if this is not possible, by deep burial of at least six feet with one foot of quicklime above and below it. Milk from diseased or suspected animals must not be mixed with other milk, and that from affected animals must be efficiently sterilized.

BOVINE CONTAGIOUS ABORTION.—This disease, which is characterized by a chronic inflammation of the uterus resulting in a premature expulsion of the fœtus usually between the fifth and eighth months of gestation, is produced by a specific organism (*Bacillus abortus*, Bang). Although it is recognized that the causes of abortion are very varied, it cannot be too strongly urged that the contagious form of the disease, which is, unfortunately, widely disseminated amongst the herds of this country, occasions by far the greatest losses, and constitutes a menace to the dairy farmer equal in importance to the losses caused either by Tuberculosis or by Johne's disease. The source of infection is always traceable either directly or indirectly, to a previous case, the disease being frequently introduced through the agency of freshly purchased animals from unknown sources. As a general rule, a cow which has aborted once is not likely to calve prematurely at subsequent pregnancies, but it is important to remember that such animals often become "carriers," *i.e.*, they harbour the organisms in their bodies for many years, during which period they are a potential source of danger, particularly at each parturition period. The aborted calf, the membranes and the discharges from the uterus are highly infective and are liable to spread the disease to neighbouring animals, and in particular to pregnant animals: for this reason it is advisable to regard any abortion as the contagious form until the contrary can be proved, and to take the most rigorous steps to prevent the spread of infection to other in-calf animals.

Cows which have aborted or have calved before full term must be immediately isolated, and the attendants should be instructed to observe the most scrupulous care in disinfecting their boots and clothing. Infective material must be destroyed, particular care being directed towards discharges from the uterus, cleansings, etc. The animal should not be returned to the herd until all discharge from the uterus has entirely ceased. It is possible by means of a special test on the blood serum to determine almost with certainty whether an animal is affected with the contagious form of the disease.

In view of the serious nature of the affection, many owners are desirous of maintaining an abortion-free herd. The first step is to submit a sample of blood from every animal in the herd to the test: if this reveals that the entire herd is composed of non-reacting animals, the utmost care should be taken to avoid the introduction of the disease, and the owner cannot be too careful regarding additions to it, no animal being allowed to enter the herd until it has been proved to be free from it. Should the test show that the disease has already established itself, two courses are open to the owner depending upon the degree of infection and the extent of the accommodation. If the reactors are few in number, it is possible to build up a free herd by entirely separating the reactors from the non-reactors, the former being either sold or segregated on entirely separate premises. The buildings which are to house the non-reactors must be efficiently disinfected (see Disinfection), and the herd must be subjected to periodic tests in order to detect animals which may become positive reactors subsequent to the previous test. The calves from the reacting animals, if separated soon after birth, can be used to supplement the clean herd. If, however, the initial number of reactors is large, or it is not possible to segregate the reactors, the owner may be compelled to maintain his herd as an abortion-infected unit. Under these circumstances, it must be remembered that the infected animals are valuable as they are unlikely to abort again, but that abortions may occur in non-reacting animals which are introduced into the herd. In order to guard against this accident, it may be necessary to inoculate all susceptible animals with an anti-abortion vaccine about two months before they are put to the bull.

Contagious forms of abortion also occur in the mare and in the sheep: in general, the preventive measure advocated for cattle apply also to these animals.

By the Epizootic Abortion Order (1920), powers are given to Local Authorities to make regulations to prevent the exposure for sale in a market or sale-yard of any bovine animal which has calved prematurely within the preceding two months, and to prohibit the sale of such an animal unless notice in writing has been previously given to the purchaser.

Foot and Mouth Disease.—This acute and highly infectious condition attacks cattle, sheep and pigs, and derives its name from the characteristic vesicles (or blisters) which are formed on various parts of the body, in particular in the mouth and on the feet. It is caused by a virus which is abundantly present not only in the lesions, but also, at certain periods, in the blood and the various secretions of the body, *e.g.*, milk, urine, etc. The mortality amongst adult animals, especially in countries where the disease is enzootic, is usually comparatively low, although the losses may attain serious proportions in the case of young stock. Apart from the actual death of affected animals, however, the disease is of serious import on account of its proclivity for rapid spread, and also on account

of the great economic losses which it causes through diminished milk secretion and severe loss in condition of fat stock. In this country, the most rigorous measures are directed against the intro duction of the disease from outside sources, and the prevention of its spread in the event of the disease gaining a foothold. It is often a matter of considerable difficulty to trace the source of infection in these outbreaks which, in spite of all precautions, occur from time to time: it is known, however, that under certain conditions, the virus is capable of maintaining its vitality over considerable periods of time. The importation from countries in which the disease exists, of hides, packing material and foodstuffs which have been in contact with affected animals, or of the carcasses of diseased animals, have frequently been the agents whereby the disease has been introduced into this country. Once the disease has established itself, it is prone to spread with great rapidity, either through the immediate contact of diseased with healthy animals, or by mediate methods through the contamination of the person or the clothing of attendants, foodstuffs, buildings, markets, railway trucks, etc., with discharges from the lesions. It is important to bear in mind that during the febrile reaction which precedes the appearance of visible lesions, the affected animals are highly infectious, and thus the disease may become well established before its true nature is realized. The chief symptoms of the condition are a marked depression accompanied by a rapid rise in temperature, followed by a profuse salivation coincident with the formation of the vesicles. In sheep and pigs, foot lesions are more common, and the sudden occurrence of lameness amongst a number of animals should be regarded with suspicion. It is incumbent upon an owner, in the interests of himself and his neighbours, to be on his guard and to seek advice without delay.

The disease is scheduled under the Diseases of Animals Acts and outbreaks must be instantly reported to the Local Authorities. Immediate steps are taken to prevent the spread of the disease by prohibiting all movement to and from infected premises, except under licence, and by the slaughter of all affected or in contact animals: in addition, a thorough disinfection of the premises is enforced, including disinfection of persons leaving the farm, and a "stand still order" is imposed upon an area with a radius of about fifteen miles around the infected premises.

Tuberculosis is a contagious disease affecting various domestic animals caused by a specific organism (Bacillus of Tuberculosis or Koch's bacillus). Unfortunately, in this country, as in many others, the disease is widespread amongst cattle, and is responsible for enormous losses to the stock owner. It has been estimated that between 30 and 40 per cent. of dairy cattle are infected, and in some herds the proportion is considerably higher; in the beef breeds, on the other hand, the disease rarely exceeds 10 per cent. The relatively high inciden of the disease in housed animals is

undoubtedly dependent upon the close co-habitation of dairy cattle, and to their greater length of life which favours the chances of exposure to infection. In the majority of animals, the disease is essentially chronic in nature and is therefore most insidious; moreover, even in the acute stages, the symptoms are often obscure to any but a trained observer. The disease may be suspected in animals which show a persistent loss in condition especially if this is accompanied by a chronic cough or by indurative changes in the udder. The tubercle bacilli are discharged by way of the expectorate, the fæces and the urine, and also through the milk. Transference of the disease from affected to healthy animals takes place through the inhalation of air which is laden with infective particles of sputum from a case of open tuberculosis of the lungs, or by the ingestion of contaminated foodstuffs and water. The spread of the disease is also facilitated by badly ventilated and ill-kept buildings, and by the neglect of simple measures of disinfection. Infection in young calves almost invariably results from the feeding of raw milk from tuberculous cows. The disease occasionally occurs in the horse, and is by no means uncommon in the pig and the fowl. Amongst poultry, the organisms are passed from bird to bird by means of infected droppings. In the pig, infection may arise from two sources; in many cases these animals are infected with the bovine type of the organisms through the incorporation in the food of unboiled milk from tuberculous cattle, whilst a proportion of pigs suffer from the avian type of the disease through contact with tuberculous poultry.

Since tuberculosis is a disease which results largely from close confinement, it is advisable to keep animals in the open air as far as is practicable, whilst byres and cowsheds should be well ventilated and frequently cleansed with a suitable disinfectant solution (see Disinfection).

In view of the serious economic losses which are sustained through the disease, an owner may desire to attempt the building up and the maintenance of a tubercle-free herd: this is not a task which can be lightly undertaken, but its feasibility has been proved both in this and in other countries. The first step comprises the application of the tuberculin test (a method of detecting tuberculous animals) to the whole herd in order to pick out the affected beasts. Those which react must be either entirely eliminated, or else segregated on separate premises with separate attendants, whilst the unaffected animals are housed in adequately disinfected buildings. The clean herd must be subjected to a tuberculin test at least once every six months so that any animals which have subsequently become infected, may be detected in the early stages of the disease and eliminated before they can contaminate the non-infected animals. The herd can be supplemented by the addition of calves from both non-reacting and reacting mothers, but, in the latter case, these calves must be segregated at birth and reared

either on milk from the non-reactors, or on pasteurized milk. Freshly purchased animals should not be directly introduced into the herd, but should be isolated until they have been tested.

The Tuberculosis Order (1925) aims at the suppression of clinical cases of tuberculosis. Under the provisions of this Order, a person having a bovine animal which is suffering from tuberculous emaciation or from chronic cough, or showing clinical symptoms of tuberculosis of the udder, is responsible for the notification of the case to an officer of the Local Authority. Such an animal must be slaughtered, the owner receiving compensation. Powers are also conferred on Local Authorities for the procuration and examination of milk samples with a view to the detection of tuberculous milks.

JOHNE'S DISEASE is a chronic malady characterized by a gradual loss in condition usually accompanied by a profuse and persistent diarrhœa. The disease is almost entirely confined to cattle, although, on rare occasions, cases have been reported in the sheep and the goat. The cause of the disease is a micro-organism (Bacillus of Johne) which, in some respects, resembles the tubercle bacillus, although the diseases have no other feature in common; in fact the two may exist side by side in the one animal. The lesions are confined to the intestines and to the adjacent lymph glands, whilst a frequent and striking post-mortem feature is a very characteristic thickening and corrugation of the intestines. The organisms are passed out in the fæces and, since they possess considerable powers of resistance, may remain alive for lengthy periods outside the animal body. Infection takes place through the ingestion of contaminated foodstuffs, water, etc.

In view of the insidious nature and slow spread of the disease, and the lack of efficient means of treatment, it cannot be too strongly urged that the most stringent preventive measures are justifiable: they include the destruction of clinically affected animals and the isolation of those which are under suspicion. Special attention should be paid to contaminated pastures, and to ponds which are a frequent source of infection to clean stock. The droppings should be spread over the land and then ploughed in, whilst the pastures may be treated with quicklime: a thorough disinfection of the buildings and yards is also of the utmost importance. The detection of early cases of the disease is facilitated by the application of a special test similar to the tuberculin test.

SWINE ERYSIPELAS, an infectious disease of pigs caused by a specific organism (Bacillus of Swine Erysipelas), is widespread in Great Britain, and is sometimes responsible for greater losses than the other important swine disease, namely Swine Fever. The disease, which attacks pigs of all ages, is characterized by a high fever and the production of peculiar purplish discolorations of the skin from which the disease derives its name. The mortality varies considerably, for in some outbreaks it may be as high as 90 per

cent., whilst in others the losses may not exceed 5 per cent. An acute and a chronic form of the disease are recognized; in the former the symptoms develop rapidly and death often ensues through the invasion of the blood stream by the organisms. In these outbreaks, the disease is readily transmitted from one animal to another by the excretions of affected pigs. The chronic form in which the symptoms are mild and recovery is the rule, is most insidious because these recovered pigs, by harbouring the organisms in their bodies, are a fruitful source of the maintenance and dissemination of the condition. Outbreaks are especially liable to occur in hot, dry weather, presumable because these conditions favour the survival and spread of the organisms.

Preventive measures comprise the strict isolation of infected pigs and the destruction of contaminated material. In this connection, it must be pointed out that the organism seems to be capable of a prolonged existence in manure heaps which are frequently responsible for fresh outbreaks: it is also a wise precaution to segregate freshly purchased animals for three to four weeks. In districts where the disease is enzootic pigs may be rendered immune by the application of certain methods of preventive inoculation; in addition, the inoculation of affected animals with a specific serum in the early stages of the disease will generally bring about a recovery.

SWINE FEVER.—The pig is the only animal which is susceptible to this highly infectious condition which may be regarded as epizootic in this country. The disease is caused by a virus, and is characterized by a febrile reaction accompanied by a general depression, capricious appetite, loss in condition and diarrhœa. In young pigs, the disease frequently occurs in an acute and fatal form, whereas in older animals it shows a tendency to assume a more chronic aspect: the mortality varies from 5 per cent or less in mild outbreaks up to 70 to 90 per cent. in the severer outbreaks. Although the disease can often be recognized, especially in the more chronic cases, by the appearance in the intestines of affected pigs of the highly characteristic "button ulcers," it must be remembered that in the acute cases, these typical ulcers are often lacking: in consequence, the acute diagnosis of the disease is not easy and must rest in the hands of the trained expert. Since the disease is extremely contagious, infection is readily transmitted, either directly or indirectly, from affected to healthy animals. As in the case of foot and mouth disease, to which in the matter of its spread, it bears a close resemblance, the virus is easily disseminated by labourers, dealers and other persons whose habitments may have become contaminated with infective material. The "carrier" pig presents a difficult problem in schemes which aim at the eradication of the disease, for animals which have survived a previous attack and have apparently made a complete recovery may yet harbour the virus in their bodies, and thus

introduce the disease if brought into contact with susceptible pigs; an unthrifty appearance is often associated with this chronic form of swine fever.

With a view to preventing the introduction of the disease breeders should, as far as possible, rely on pigs of their own breeding *for the maintenance of their stock; should it be necessary to purchase animals from outside sources, it is advisable to isolate* them for about a month after an outbreak; the methods of disinfection should follow the lines laid down for foot and mouth disease.

In this country, swine fever is a scheduled disease and must be reported to the Local Authorities. Infected premises are put under a Detention Order, whilst carcasses or portions thereof may not be removed except by permission of a responsible officer. Regulations are also laid down for the disinfection of premises, the disposal of carcasses and the movement of in-contact animals.

TETANUS (Lockjaw).—This disease, which is caused by a specific organism (*Bacillus tetani*), owes its name to one prominent symptom, *i.e.*, an inability to open the jaws; nevertheless, it must be remembered that many cases of tetanus fail to show this characteristic symptom. The condition is frequently encountered in the horse, but may also occur occasionally in calves and lambs. The organism is a normal inhabitant of the soil, more particularly of soil which has been contaminated with horse manure. The disease almost invariably follows the introduction into a wound, especially a punctured wound, of the tetanus bacillus or its spore; hence, tetanus is very liable to follow picked up nails, pricks in the feet and injuries in the hunting field. In the foal and other young animals, the disease is not an uncommon complication of the operations of castration and docking. The mortality, especially in young animals, is very high.

In all cases of open wounds, particularly the wounds of castration and shearing, every endeavour should be made to avoid contamination with soil. As soon as symptoms appear, a search should be made for a wound which is likely to harbour the organisms, and this must be freely opened and disinfected. In the case of a picked up nail or other injury of this nature in the horse, it may be advisable to seek professional aid with a view to the preventive inoculation of anti-tetanic serum which, if administered in time, will prevent the development of the disease.

BLACK QUARTER. (Quarter-ill).—This malady, which has some clinical resemblance to anthrax, is caused by a specific microorganism (*Bacillus chauvœi*) which also has its habitat in the soil; unlike the tetanus bacillus (see Tetanus), however, which is found in all localities, black quarter is confined to definite districts and farms. Cattle and sheep alone are susceptible to the disease which may arise either through the introduction of the spores of the organism into abrasions on the legs or feet, or through infection by way of the digestive tract. The most striking symptom of the

disease is the development of the so-called " black quarter tumours " in certain groups of muscles which become dark in colour and gaseous, causing a peculiar crackling of the skin when the hand is passed over the affected region. The mortality is high and curative measures are practically useless.

In the event of a single case of the disease, the most rigorous disinfection may prevent further trouble, and the measures which have been considered under the heading of Anthrax for the disposal of carcasses and disinfection of premises, apply equally well to black quarter. In localities where the disease is enzootic, the soil should be ploughed up, or else cattle and sheep should be debarred from the affected pastures. In these black quarter districts, the young stock can be rendered immune to the disease by one of the methods of protective inoculation, and in badly affected areas this is carried out as a routine measure.

ACTINOMYCOSIS (Lumpy Jaw) and ACTINOBACILLOSIS (Wooden Tongue) are two diseases which are often confused; they are chronic infections, but not obviously contagious, affections which are seen chiefly in cattle, although occasional cases are encountered in the sheep and the pig. These diseases occur with greater frequency on low lying damp pastures than on higher, well drained land. Cattle are liable to contract infection through eating contaminated awns which may injure various parts of the tongue and the mouth; the period of the eruption of the teeth also facilitates the entrance of the organisms. The disease is characterized by the appearance of a diffuse thickening of the tongue, or of dense swellings situated in the neighbourhood of the bones of the jaw, or in the adjacent lymphatic glands: these indurated swellings, which may attain a considerable size, are often the seat of suppurative changes. Lesions are occasionally found in other parts of the body such as the lungs, the liver and the udder. The disease always runs a chronic course extending into months or even years. In some cases, early treatment by means of the internal administration of potassium iodide will bring about a recovery, but in advanced cases, except for a valuable animal, a prolonged course of treatment is rarely an economic proposition. Although the disease is generally regarded as non-contagious, it is advisable to isolate any infected animal which shows discharging lesions.

JOINT-ILL is an affection of the newly-born animal, chiefly the foal, the calf and the lamb, characterized by a swelling of various joints and usually associated with an abscess formation at the navel. In most outbreaks infection arises through the contamination of the umbilicus with various soil organisms which multiply there and later invade other parts of the body. Affected animals show symptoms of systemic disturbances together with hot, painful swellings of the joints. The mortality is usually about 50 per cent., whilst recovered animals are so unthrifty that curative measures are rarely worthy of consideration. An important

contributory factor to the maintenance and spread of the disease is the continued use of the same buildings for successive parturitions without adequate disinfection.

On premises where the disease occurs with regularity, it is advisable to allow parturition to take place in the open: if this is not feasible, then the most scrupulous attention must be paid to the disinfection of boxes and pens. The application of a mild antiseptic lotion to the umbilicus at the time of birth is a valuable aid to the prevention of infection; the navel cord may be tied with antiseptic tape and the stump treated with tincture of iodine.

WHITE SCOUR of young stock is a form of acute enteritis characterized by a persistent diarrhœa, which may be complicated by pneumonia and abscess formation in different organs of the body. As in the case of joint-ill, the disease often arises from a navel infection, but it may also spread from animal to animal through the ingestion of contaminated food-stuffs. The preventive measures suggested for joint-ill are also applicable to this condition.

METHODS OF DISINFECTION

Since diseases are readily spread from infected to susceptible animals by close contact, it follows that in any infectious disease, separation of the healthy stock from the infected or suspected animals is a very necessary preliminary step; unfortunately, this does not necessarily remove all danger of infection, since many of the disease-producing organisms are possessed of considerable powers of resistance outside the animal body, and, unless they are destroyed, may set up fresh cases. Disinfection is a process with aims at the destruction of these micro-organisms, but it is to be feared that the principles governing thorough disinfection are often imperfectly understood.

The methods which may be adopted for the disinfection of a building will depend to some extent upon the type of building which is to be treated. A modern construction with impervious floors and simple fittings is relatively easy to free from infection, whereas the thorough disinfection of an ill-constructed stable or cow house is no easy task. In the first place, all litter and dirt should be collected and burnt, especial attention being paid to cracks and crevices where micro-organisms might rest. The walls should then be scrubbed with hot soda solution, and any part of the buildings which are composed of impervious material, *e.g.*, concrete or brick, treated with a disinfectant solution. Lysol or Jeyes' fluid in a 2 per cent. solution are very reliable; chloride of lime is also a cheap and efficient disinfectant used in the proportion of one pound to two gallons of water. Lime wash, a popular and widely used mixture, is distinctly uncertain in its action and should be reinforced by the addition of a disinfectant of known potency, *e.g.*, carbolic acid, lysol. In the case of woodwork, the blow-lamp is undoubtedly the most effective form of

disinfection especially where the boards do not fit closely and cracks are formed which cannot be reached by liquid disinfectants.

If, owing to the nature of the construction of the building, the above-mentioned methods cannot be applied, it may be necessary to resort to fumigation. In order that this method shall be efficient, the building must be rendered air-tight by blocking up every door, window and crevice which might enable the gas to escape. There is a wide range of gases which may be used, but sulphurous acid or formaldehyde are probably as efficient as any of the more expensive preparations. The building should be kept closed for twenty-four hours after the liberation of the gas. Direct sunlight has a powerful germicidal action. In addition to the disinfection of buildings, it is also necessary to pay attention to the utensils, grooming kit, harness and any movable fittings ; moreover, the yards and pastures must not be neglected. Under the Diseases of Animals Disinfection Order of 1906, the following disinfectant solutions are recommended :—

(*a*) A 1 per cent. (minimum) solution of chloride of lime containing not less than 3 per cent. available chlorine ; or

(*b*) A 5 per cent. (minimum) solution of carbolic acid containing not less than 95 per cent. actual carbolic acid, followed by a thorough sprinkling with lime-wash ; or

(*c*) A disinfectant equal in efficiency to the above-mentioned solution of carbolic acid.

DISEASES OF ANIMALS ACTS

In this country the control of certain contagious diseases is governed by the Diseases of Animals Acts, which are administered by the Ministry of Agriculture and Fisheries and Local Authorities, and under which the following diseases are scheduled :—Anthrax, Cattle Plague (Rinderpest), Foot and Mouth Disease, Glanders, Epizootic Lymphangitis, Parasitic Mange of the Horse, Contagious Pleuro-Pneumonia of Cattle, Rabies, Sheep-pox, Sheep Scab and Swine Fever. Epizootic Abortion of Cattle and Bovine Tuberculosis are subject to certain specialized forms of control. These Acts have been framed with the ultimate object of the eradication of these diseases ; in some cases, notably in Cattle Plague, Pleuro-pneumonia, Sheep-pox, Rabies, Epizootic Lymphangitis and Glanders, this object has been accomplished for these diseases have been completely eradicated. Under these Acts, the notification of scheduled diseases is compulsory, and the onus of reporting a suspected case rests, in the first place, upon the owner : failure to give prompt notification renders the person in question liable to a heavy fine. If there are the slightest grounds for suspicion that a notifiable disease is in existence, the owner, in his own interests, should consult a practitioner without delay. In addition to notification, the general regulations provide for the separation of diseased from healthy animals, the provision of

facilities for cleansing and disinfection, the prohibition of exposure of diseased animals, the digging up of carcasses, etc. Full details are supplied in the Handbook on the Diseases of Animals Acts.

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CHAPTER XXVIII.

INSECTS.

ZOOLOGISTS recognise, among Invertebrate animals, an immense group known as the Arthropoda, characterised by having their hard parts, to which the muscles are attached, almost entirely external. This hard integument, composed of a special horny substance called chitin, necessitates the presence of joints, and the body and limbs are therefore divided into segments articulating with one another. The name Arthropoda means the animals with jointed limbs.

One great section of the Arthropoda—the Crustacea (crabs, lobsters, shrimps, etc.)—are water animals, breathing by gills, and

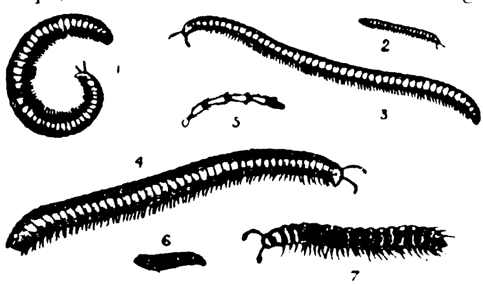

FIG. 122.
MILLIPEDES (Myriapoda.) 1 7 various species of.

of no importance to the agriculturist. One single example—the wood-louse—has taken to life on land, and is to be found everywhere, sometimes doing considerable harm, especially under glass.

Of the air-breathing Arthropoda, three groups claim our attention —Myriapoda, Arachnida and Insecta. The Myriapoda are the centipedes and millipedes, characterised by the possession of a large number of legs all through their lives. The centipedes are generally flat-bodied, have poison fangs just behind the head, and never have more than one pair of legs to a segment. They are carnivorous and

therefore to some extent beneficial to the farmer, since they prey upon insects. The millipedes are generally more cylindrical, without poison fangs, and many of their segments bear two pairs of legs. They are vegetarians, and some species are highly injurious to seedlings and to stored roots. (Fig. 122.)

The Arachnida comprise the scorpions, spiders, mites and many less familiar animals. They are never winged, and are typically eight-legged when mature. The only group of agricultural importance is that of the mites, some of which (*e.g.* red spider and gall-mites) do much harm to crops, while others (itch-mites and ticks) infest domestic animals.

The Insecta are the largest group of the Arthropoda. They are the only invertebrates that ever have wings, so that the possession of wings is alone sufficient to identify any given example as an insect.

Very many insects, however, never develop wings, so that other characteristics have to be looked for, and the most obvious is the possession of six legs when mature. Other peculiarities may be gathered from the following brief description of the external structure of an insect.

EXTERNAL AND INTERNAL STRUCTURE

The body of an insect consists of three regions, head, thorax and abdomen. Each region consists of a certain number of segments, more or less fused together. Research has shown that the head is really formed by the fusion of six segments, but it now appears as a single mass. The thorax consists of three segments, sometimes obvious (*e.g.* the cockroach) but sometimes entirely fused (*e.g.* the house-fly). Each of these segments bears a pair of legs, and the second and third segments may bear wings. The abdomen theoretically consists of twelve segments, though the visible segments are often much fewer in number. There are no legs on the abdomen but appendages called *cerci* may be seen proceeding from the posterior end in some insects.

The whole body is covered by chitin, but to admit of movement this must be thin and flexible in parts, so we find that there are a series of dorsal plates (*terga*) and ventral plates (*sterna*) of stouter chitin connected to one another at the sides and in succession along the body by intervals of thin flexible chitin.

The head bears the antennæ, the eyes and the mouth-parts.

The antennæ or feelers are of very varied design. The characteristic eyes of the imago are compound, consisting of a number—often very large—of facets, each of which is a complete eye element in itself. There may also be a few simple eyes or *ocelli*. The larvæ never have compound eyes, but they sometimes possess *ocelli*. Insects differ very much in the nature of the mouth apparatus, some obtaining their food by suction, others by biting, but there is reason to believe that the biting mouth has given rise to all the other forms by modification of its different elements, so that it is important that its nature should be clearly understood.

There is a simple upper lip (*labrum*), and a complex under lip (*labium*), between which two pairs of jaws work horizontally, and not vertically. These are the *mandibles* or biting jaws, and the *maxillæ*, whose function is to test the food and push it in for the mandibles to crush. In such insects as the cockroach it is easily seen that the *labium* is really formed of a pair of organs very like the *maxillæ* fused together, and indeed the *labium* is sometimes called the *second maxillæ*.

The segments of the thorax are known as the pro-thorax, the meso-thorax and the meta-thorax, and each bears a pair of legs. Each leg consists of five portions, the *coxa* which attaches it to the thorax, a small joint called the *trochanter*, then the *femur* or thigh, the *tibia* or shank and finally the *tarsus* or foot, which consists of two to five joints and generally terminates in a pair of claws. The wings are membranous out-growths from the meso- and meta-thorax and are generally strengthened by veins or *nervures*.

It is unnecessary here to discuss in detail the internal organs of an insect, and most of them will be dealt with very briefly. It is noteworthy that their general arrangement is just the reverse of what is found in vertebrate animals. The heart, for example, is a tube of several chambers lying quite dorsally, while the nervous chain is for the most part ventral, the alimentary canal lying between them. The only part of the nerve chain lying dorsal to alimentary canal is the "brain" in the head, and from this two *commissures* go round the gullet to unite again in a chain of nerve-knots or *ganglia* in the thorax and abdomen.

It is important, however, that the breathing apparatus should be clearly understood. Vertebrate animals have definite organs—lungs or gills—to which both air and blood are admitted, and in which an exchange of oxygen and carbon-dioxide can take place. There is no such organ in insects (except in the larvæ of aquatic forms), but by a system of tubes called *tracheæ* air has access to every part of the body, and the exchange takes place in the tissues themselves. The main trunks of these *tracheæ* communicate with the exterior by pores called *spiracles*, capable of being opened or closed, and these pores are generally situated at the sides of the insects. In some larvæ, such as caterpillars, they are often conspicuous along the sides, while dipterous maggots possess a posterior pair of spiracles which are easily seen. Thus the breathing system is quite separate from the alimentary canal. Many insects produce sounds but never, as in vertebrates, by air proceeding from the mouth—since insects breathe though their sides. In their case sound is produced by scraping or "stridulation," and the stridulatory apparatus is very varied in different insects.

On dissecting an insect the *tracheæ* may be seen ramifying to all parts of the body and the air they contain gives them a silvery appearance. High magnification shews that they contain a spiral filament of chitin which helps to keep them distended, just like the spiral coil of wire in a hose-pipe.

MOULTING AND METAMORPHOSIS.

We have seen that insects, with the rest of the Arthropoda, are covered by a chitinous exoskeleton. Chitin is incapable of rapid growth, and does not stretch easily. It follows that if the young insect is to make any considerable increase in size it must cast its chitinous skin at intervals and form a new one. This operation of moulting or "ecdysis" is performed by all insects during their period of growth. It is not unattended with danger, for limbs are sometimes lost in the process, and until the new chitin has hardened the insect is especially vulnerable. When about to moult, therefore, an insect generally seeks some natural shelter, or covers itself with a cocoon.

No insects emerge from the egg in precisely their final form. Wings, for instance, show no sign of appearing till the last moult but one, and are not fully formed till the last moult, and it is then only that the insect becomes sexually mature. Some insects exhibit little change of appearance or habit after each moult—at all events until the final ecdysis when the wings appear. An earwig, for example, is recognisable as an earwig when it hatches from the egg. Other insects present an entirely different appearance after certain of their moults, as in the familiar case of the butterfly. From the egg hatches out a caterpillar, which, after several moults, changes to a chrysalis, from which presently emerges the butterfly, the different stages being quite unlike each other. These changes are summed up in the term metamorphosis. In insects like the earwig, where the changes are slight, metamorphosis is said to be incomplete; in insects like the butterfly, where the changes are abrupt and striking, it is said to be complete. Whatever the degree of metamorphosis it is usual to recognise four stages in the development of an insect—egg, larva, pupa and imago. The larva is very frequently some sort of grub, but may, as we have seen, be like a small edition of the mature insect. The pupa is often a resting stage (*e.g.* a chrysalis), but in insects with incomplete metamorphosis it is active, and generally shows the beginning of wings. Such an active pupa is often called a nymph. The imago is the sexually-mature insect, and the wings, if it is to possess any, are now complete. No further growth takes place—small flies do not become big flies.

The sort of entomological knowledge useful to an agriculturist is of rather a special nature, and differs widely from that possessed by the average collector of beetles or butterflies. Injury is more often done by the larvæ than by the mature insects, and therefore a study of larval forms is highly important. A student should be able to recognize a larva not only as belonging to a particular order of insects, but, in many cases, to a special group within that order. Until he can do this, the various books on pests and how to deal with them are of little use to him. If he recognises the larva as that of a sawfly, it is easy to discover the species of sawfly known to attack that crop and to find out what measures are recommended against it.

Fortunately many comparatively small groups of insects have very characteristic larvæ, and one soon becomes familiar with them.

IMPORTANCE IN NATURE

Notwithstanding their insignificant size, insects are of vast importance in the economy of nature. This is mainly due to their immense numbers, and the rapidity of their increase. About 450,000 different kinds of insects are already known, and their number is being constantly added to. Then the individuals of a single species may on occasion become so numerous as to defy calculation, as in the case of a swarm of locusts, or an aphis attack. In wild nature they are the great scavengers, quickly disintegrating dead animals and fallen trees; they cross-fertilize entomophilous flowers; some devour the tissues of plants and others prey upon these marauders, so that a general balance is struck, seldom disturbed by the preponderance of any one species.

Now the operations of civilized man entirely upset this general balance of nature. When, for example, he devotes thousands of acres to the growth of a single plant the insects which live on that plant, and which could only just maintain themselves in a mixed vegetation, naturally tend to increase beyond all measure, and it becomes necessary to take steps to counteract their activities.

In civilization man is affected by the insect world in a variety of ways, some beneficial, and some highly injurious. It is common knowledge that several commodities—silk, honey, wax, cochineal, shellac, etc.—are obtained directly from insects. Then the function of cross-fertilizing flowers remains of the highest importance, many of his crops being entirely dependent on the visitations of insects. Moreover, he naturally regards as beneficial the parasitic or predaceous insects which prey upon those which do him injury.

But attention is more often attracted to insects by their injurious activities. There are serious insect-borne diseases contracted by man himself—malaria carried by mosquitoes, plague by fleas, sleeping sickness by tsetse flies, and many others. Some (warble-fly, sheep maggot, etc.) directly attack domestic animals, and others infect them with blood parasites. Every kind of crop is subject to attack by insects which tend to increase the more extensively the crop is grown, and many are the ways in which injury is inflicted. The germinating seeds may be devoured and the whole crop destroyed at the outset or destruction may occur at a later stage by the ravages of caterpillars. Many insects inflict fatal injury by extracting the sap and causing the plant to wilt without any direct destruction of tissue. Then again there are a host of insects which, though not fatal to a crop, do great harm by decreasing the yield or diminishing the market value of the produce. In this category we may place such pests as the clover seed weevil and the Capsid bug of the apple. Finally, stored products are subject to insect attack; roots in the clamp or cereals in the bin.

GENERAL PRINCIPLES OF TREATMENT.

Some insect pests are general feeders (polyphagous), showing little partiality for any particular crop. Others (monophagous) are only attracted by one crop or at all events by a few crops which are closely allied. The former are the most difficult to deal with, for the latter, the monophagous pests, may be partly counteracted by a proper rotation of crops. If no crop to their taste is grown the following year on the same ground or its immediate neighbourhood they are starved out. Some crops are so remunerative that the farmer will continue to grow them in spite of the pests which are thereby encouraged, and he then has to take special measures to counteract their attack.

Rotation, then, is of primary importance in the case of many injurious insects. Other measures to restrict their operations fall chiefly under three heads:—(1) Biological control; (2) Cultural methods; (3) Insecticides.

Biological Control.

We have seen that in wild nature parasitic and predacious insects more or less control the abundance of injurious insects and establish a balance so that no form predominates. When this balance is disturbed by the cultivation of crops it is still sometimes possible, by the special encouragement of useful insects, birds and mammals, to call in the aid of this "biological control." It is customary, for example in forestry, to provide nesting boxes for tits and other insectivorous birds. With regard to parasitic and predaceous insects the case is less simple where well established pests are concerned, because if the control insects are not there they are not likely to be anywhere else. Nevertheless we often notice that a pest, after occuring with increasing virulence for a few years, suddenly disappears, because its parasites have increased even more rapidly. The oak tortrix moth is a good example.

But it is in the case of introduced insect pests that biological control may be called in with extraordinary effect, as may be best explained by citing a classical example. In 1880 the orange and citrus ranches of California were threatened with utter destruction by the depredations of a scale insect, *Icerya purchasi*. It was found that the scale insect was a native of Australia, where it was not greatly destructive, being more or less kept in order by a variety of predaceous insects—notably by a lady-bird beetle, *Novius cardinalis*. The lady-bird was obtained from Australia and established in the Californian ranches, where it speedily cleared out the scale and then died of starvation. It is important to realize exactly what had happened. The scale, introduced into a country where its food was abundant and its natural enemies non-existent, increased out of all measure. But the same was also true of the lady-bird, which doubtless left behind it various enemies in Australia and found any amount of scale on which to feed—at least for a time.

It is clear, then, that the introduction of predaceous or parasitic insects obtained from the country of origin of an introduced pest may be of extreme utility, but a warning must be given against the unconsidered introduction of any animal into a new country, as the results of such introduction have in many cases proved disastrous, often on account of a change of habit on the part of the creature introduced. Among insects there are, at all events, two groups which it is fairly safe to utilize in this manner : lady-birds and ichneumon flies. Pests are constantly being introduced into our Colonies and Dominions, and in such cases it is the regular procedure now-a-days to seek the natural enemies of the pest in its country of origin and transport them to the newly infested district. The Imperial Institute of Entomology has recently established at Farnham Royal a Parasite laboratory for the sole object of breeding out the enemies of various insect pests and supplying them to those Colonies in which the pests have obtained a footing.

Cultural methods.

These are chiefly directed towards the prevention of the recurrence of an attack, and rotation of crops is by far the most important. Other cultural methods follow naturally from long farming experience or from facts observed in the life-history of a particular pest. This may best be illustrated by the citation of a few examples.

It is the common experience that crops sown on broken up grass land are subject to severe attacks of "wire worm" and "leather-jacket." It is therefore unwise in such circumstances to attempt to take a cereal crop, which may be entirely destroyed on germination, and which, even if it survives, admits of no cultivating operations which may clean the ground for future crops. If, on the other hand, seed potatoes are put in they will doubtless suffer but may yet give a fair yield while the routine cultivation of the crop will do much to turn the grubs out for the birds to prey on.

The date of sowing is sometimes of importance. Late sown oats, for instance, are always most severely attacked by frit-fly, and the farmer, knowing this, will make a special effort to sow his oats as early as the weather will permit.

As an example of cultural methods depending on the peculiarities of a particular pest, the case of the wheat-bulb fly may be cited. Long experience has taught farmers that winter wheat is always most attacked if sown on land which was fallow the previous summer, and investigation has shown that the insect does in fact lay its eggs on bare soil. It is therefore important to ensure that land on which it is proposed to grow winter wheat should be well covered by some crop or other during July and August.

Crops grown for seed are sometimes attacked by insects which infest the flower (clover by weevils, sainfoin by the midge, etc.). It then becomes a problem to the farmer whether he shall persist in taking a seed crop with the likelihood of a poor yield and the certainty of breeding out vast numbers of the pest to attack other

crops, or whether he shall cut his losses and make what immediate use of the crop is possible, ensuring that the pests shall not reach maturity. Ensilage may help him here, for though an infested clover stack would breed myriads of weevils, none would emerge alive from the silo pit. These few miscellaneous cases sufficiently illustrate what is meant by dealing with pests by means of cultural methods.

Insecticides.

When a pest has made its appearance it is sometimes possible to check its ravages by distributing over the crop some substance harmless to the crop but objectionable to the insect. Such substances come under the general term of insecticides. Their principal utility is in the orchard and fruit garden, but there are occasions when they may be used with advantage on arable land if a suitable distributor is available. In such cases they are generally insectifuges rather than insecticides, the object being to render the crop unpalatable to the pest. Thus, germinating peas, threatened with destruction by *Sitona* weevils, may be saved by a dressing of soot, or a spraying with dilute paraffin may warn off the "turnip-fly" from the delicate cotyledons of a root-crop.

Every fruit-grower necessarily relies largely upon insecticides. There is very little opportunity for rotation of crops, and numbers of fruit trees and bushes stand perennially in a limited space so that there is every encouragement for their insect enemies to flourish and multiply unless directly combated.

A wide variety of materials are employed as insecticides and insectifuges. Among those of vegetable origin nicotine and derris may be mentioned as especially important, while others are pyrethrum and hellebore. Generally speaking they have the advantage of being only slightly toxic to higher animals, but it is rather characteristic of them that they must be used in a fresh condition, as they deteriorate on keeping. Among those of chemical origin, or bye-products of manufactures are lime, sulphur, lead arsenate, tar distillates, etc. Some of the mineral fertilisers (*e.g.* kainit) have a certain insecticidal value in addition to helping on the growth of the crop.

In the orchard insecticides are used for a variety of purposes. Spraying operations may be roughly divided into two categories—winter spraying and summer spraying. The object of winter spraying is the clearance of the trees from hibernating pests. Formerly various caustic alkali washes were employed for this purpose. They were fairly effective but often did more damage to the trees than was immediately observable, and of recent years they have been almost entirely replaced by tar distillates, which can be used without danger to the trees and are very effective against certain pests—especially aphis.

Summer spraying is undertaken when a pest has declared itself, or when observation has shown that the eggs of some injurious insect are hatching out and attack may be expected. Here a very important question arises, namely whether the insect in question is "haustellate" —injuring the plant by abstracting the sap, or "mandibulate"— actually devouring the tissues of the plant. In the case of haustellate insects the object is to destroy them directly, and a "contact" insecticide (nicotine, paraffin, etc.) is used, generally emulsified by the addition of soft soap, for most of these insects are protected by a waxy exudation.

With mandibulate insects (*e.g.*, caterpillars), it is found more convenient to attack them indirectly, by the employment of a "poison" insecticide, the idea being to cover the leaves with a very thin layer of poison such as lead arsenate, so that the whole brood may be killed off at the outset at little cost to the foliage. Obviously here the spraying is of quite a different nature from that employed against sucking insects. The tree is not deluged with a wash, but is enveloped in a mist of the insecticide by the use of very fine nozzles, and on condensation every leaf is coated with a thin film of the poison.

There are occasions when washes are used for their merely mechanical effect. Salt and lime have been successfully employed against apple sucker, not because of any lethal properties, but because they smother the eggs and prevent them from hatching out.

CLASSIFICATION OF INSECTS

Insects are divided into Orders, and entomologists recognise about twenty-three of such divisions. This is an alarming number of principal groups, and clearly beyond the possibility of treatment in a brief review of the subject, but fortunately the agriculturalist is only greatly concerned with a very few of the orders. There are many small groups of insects, peculiar in structure, and without any near relations, and these constitute orders by themselves. Such are fleas, lice, dragon-flies, thrips and earwigs. Then again several orders are concerned entirely with insects which spend most of their life in water and have no relation to either farm animals or crops. We have only space to consider in some detail the five orders which contain nearly all the insects injurious to farm crops. They are:—

Order.	Examples.
Rhynchota (or Hemiptera) ...	Bugs, greenfly, apple-sucker, etc.
Lepidoptera	Butterflies and moths.
Coleoptera	Beetles.
Hymenoptera	Bees, wasps, saw-flies, ichneumon flies, gall-wasps.
Diptera	True flies, with two wings only, *e.g.*, house-fly, crane-fly, etc.

It will be noticed that most of the ordinal names end in the letters -ptera, the Greek πτερὰ, wings, and that by them attention is directed to some peculiarity of wing-structure in the order. In defining or "characterising" an order it is usual to pay special attention to three points, the wings, the mouth-parts and the metamorphosis. When these are known there will be little difficulty in assigning the insect to its proper order.

Rhynchota or Hemiptera. (Bugs). *Wings*—four (when present), either entirely membranous (Homoptera) or with the first pair of wings horny, with membranous tips (Heteroptera).

Mouthparts—sucking.

Metamorphosis—incomplete.

Many members of this order never develop wings—*e.g.*, the apterous individuals of the Aphidæ. The most distinctive character of the Rhynchota is the mouth apparatus. The head is produced into a jointed beak which when not in use is generally directed backwards along the ventral surface of the thorax, between the legs. The visible portion of the beak is the labium which forms a sheath within which are the mandibles and maxillæ, modified into four piercing styles. Many of the Rhynchota bear a superficial resemblance to other orders (Coleoptera, etc.), but the presence of the flexible jointed beak reveals their true nature.

Crops attacked by insects of this order suffer not by the destruction of tissue, but by the loss of sap. Their punctures, moreover, often afford means of entry to deleterious spores and bacteria.

Metamorphosis is generally very slight. The egg hatches out into a small edition of the adult insect, and only slight changes take place at the subsequent moults. If the insect is going to develop wings they appear, in a reduced form, at the penultimate moult, but are not fully developed until the final ecdysis. It is clear, therefore, that no vermiform larva found injuring crops, no sort of grub, maggot or caterpillar can be the young form of a member of this order.

The Heteroptera, in which the first pair of wings if present are partly horny and partly membranous, include many familiar insects of no economic importance. The so-called "water spiders" which skate on the surface of ponds and rivers are heteropterous bugs, as are also the "water scorpions" and "water boatmen" which are so often to be seen in fresh water aquaria. Two families of the Heteroptera are, however, of economic interest, the Cimicidæ and the Capsidæ. The Cimicidæ are the "bedbugs," wingless external parasites of nocturnal habits, not only highly objectionable in themselves but capable of conveying various diseases to their "hosts." Capsid bugs have of recent years been found to inflict considerable injury on several crops. The best-known example is the Apple Capsid *Plesiocoris rugicollis*, which attacks the fruit of the apple, much reducing the yield, and lowering the market value of what remains, since the apples are spotted and unsightly through the punctures inflicted by the bug.

The Homoptera include many insects of agricultural importance, *e.g.*, Apple sucker (Psyllidæ), White fly (Aleurodidæ), Scale insects (Coccidæ) and "Green fly" (Aphididæ). Far the most important are the Aphididæ from whose depredations no crop is exempt, and whose mode of life renders possible such a rapid and prodigious increase that an attack, unless combated at the outset, soon gets out of hand. This is largely due to the phenomenon of parthenogenesis or the production of young by females only. In its simplest form the life history of an Aphis is as follows (Fig. 123).

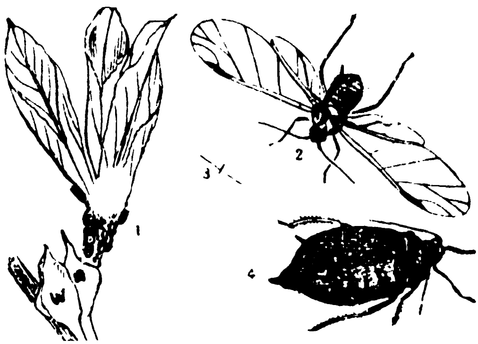

FIG. 123.
BEAN APHIS. (*Aphis rumicis*) or *A. fabæ*.
1. Infested bean shoot.
2. Winged male, magnified ; 3. Natural size.
4. Wingless female, magnified.

Males and females appear in the autumn and pair, and the females lay eggs on the appropriate food plant. In the spring these eggs hatch into wingless "brood mothers," which presently lay large numbers of eggs. These produce wingless viviparous females, of which there may be many generations before the autumn, when males again make their appearance. Obviously this method lends itself to a prodigious rate of increase, and calculations as to the potential offspring of a single "brood mother" during the summer result in numbers which convey no meaning to our minds.

The autumnal males and females are winged, and so are *some* of viviparous parthenogenetic females during the summer. These latter develop wings for the purpose of migration, and become numerous when a plant is overcrowded with aphis.

This simple life-history may be much complicated by phenomena of migration, either from a root form to an aerial form on the same plant, or from one kind of plant to another. Thus the woolly aphis of the apple, and the Phylloxera of the vine have root forms from which individuals can mount to re-infest the aerial parts of the plant, while the bean aphis migrates to Euonymus, and the hop aphis to the sloe.

That we are not entirely overpowered by pests capable of such a vast increase is mainly due to certain natural "controls." Unfavourable weather accounts for the destruction of myriads of the insects, and there are, fortunately, several predacious insects whose larvæ prey upon them almost exclusively, notably ladybirds (Coleoptera), hover-flies (Diptera Syrphidæ) and lacewings (Neuroptera). Also many ichneumon flies (Hymenoptera) are parasitic on Aphididæ.

Most aphids have a pair of *cornicles*, the so-called "honey tubes" projecting dorsally from the fifth abdominal segment. These, however, do not secrete "honey dew," which proceeds from the anus, but a waxy matter. All aphids exude waxy material from their integument, sometimes in the form of meal, sometimes as streamers and filaments (*e.g.*, the woolly aphis), and this necessitates the use of soap or resin in the contact insecticides used against them. Merely watery solutions are thrown off by the waxy exudations, and an emulsion is necessary.

Lepidoptera. (Butterflies and Moths). *Wings*—four, more or less covered by scales.

Mouth-parts—sucking.

Metamorphosis—complete.

The four wings of butterflies and moths are generally comparatively large, and not very unequal in size, and the venation is simple, with few cross veins, but their chief peculiarity lies in the fact that they are largely covered with variously coloured scales which render them opaque and give them their characteristic colour pattern. The scales, which are flattened hairs, are easily rubbed off, leaving the wings transparent. Some species, *e.g.*, the "clear-wing" moths, have considerable portions of the wings free from scales and therefore transparent, but typical scales are present in the dark bands of their wings.

Butterflies and moths are incapable of doing any harm as imagos. In many species the mouth-parts are atrophied, but most possess a proboscis, formed by the maxillæ, often visible under the head, coiled up like a hair-spring, and with this they suck the nectar of flowers or other liquid matter such as the "honey-dew" of aphis, or the juices of over-ripe fruit (Fig. 124).

The Lepidoptera present a typical example of complete metamorphosis, the four stages—egg, larva, pupa, imago—being sharply defined and quite distinct. The important stage is the larva or caterpillar, for in this stage alone is injury inflicted on vegetation, stored products, woollen goods, furs, etc. Caterpillars are of very varied appearance, but in essential points of structure they are much alike, and there is only one other kind of larva with which they are at all likely to be confounded, namely the larvæ of the Tenthredinid sawflies (Hymenoptera).

Lepidopterous caterpillars have a well-formed head, three thoracic segments each bearing a pair of five-jointed legs, and ten

(visible) abdominal segments, some of which bear pro-legs or "sucker-feet." The head bears a few scattered simple eyes on each side, and is furnished with strong mandibles. Short antennæ and maxillary and labial palps are also present, and the labium generally bears a spinneret from which emerges the silk used in making the cocoon and in other operations.

On the sides of the pro-thorax and of the first eight abdominal segments spiracles are present.

The usual number of sucker-feet is ten, borne on abdominal segments 3, 4, 5, 6 and 10. No lepidopterous caterpillar has more, and the presence of more than five pairs of sucker-feet indicates a sawfly larva. Caterpillars may, however, have fewer than five pairs of pro-legs, *e.g.*, the "loopers," in which the first three pairs are missing, and the "case-bearers" which possess only the last pair.

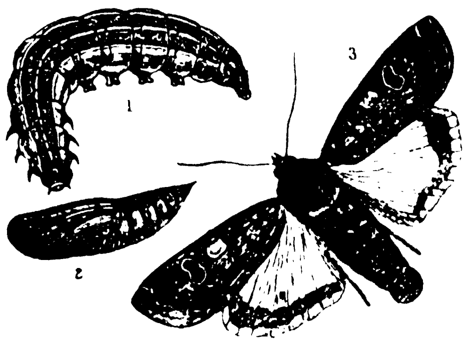

FIG. 124.—YELLOW UNDERWING MOTH, *Tryphæna pronuba* (Lepidoptera).
1, surface caterpillar. 2, chrysalis. 3, moth.

The sucker-feet of the Lepidoptera are furnished with numerous terminal hooks variously arranged.

Caterpillars are voracious eaters, and as they subsist mainly on the juices of their food they destroy an inordinate amount of tissue to obtain sufficient nourishment, and are therefore highly destructive. A few attack timber, fruit, stored food-stuffs or dead animal matter such as furs, but the usual habit is the destruction of the leaves and buds of plants and trees, and it is against them that poison insecticides are generally employed, the plant being enveloped in a mist of arsenic spray which deposits a thin film on the leaves, and the newly-hatched caterpillars are poisoned before much damage is done.

The division of the Lepidoptera into butterflies (Rhopalocera) and moths (Heterocera) is convenient but not very important. The butterflies are mostly diurnal, have rather rigid antennæ, thickened at the distal end, and hold their wings erect when they alight, while moths are mostly nocturnal, have tapering antennæ, and fold their wings horizontally or house-roof fashion. The caterpillars of all our more attractive butterflies feed on plants which we do not value

(nettles, etc.), but the "whites" (Pieridæ) have a weakness for Cruciferous plants, especially the Brassicas, and are well known agricultural pests.

In agriculture it is the orchard which suffers most from Lepidopterous pests. The injury is generally the destruction of leaf tissue and the treatment the same, whatever the species concerned. There are, however, moths of different habit, about which something must be said.

Certain moths have caterpillars which feed on timber, and attack the trunks or branches instead of the leaves. Such are the "goat moth" (*Cossus ligniperda*) and the "leopard moth" (*Zenzera pyrina*), both troublesome in the orchard, the former attacking the trunks and the latter the branches of fruit trees. Then all the "clear wing" moths (*Sesiidæ*) are timber feeders, some being recognised forest pests, while one (*Sesia tipuliformis*) attacks the branches of currant plants.

A very large family of moths, the Noctuidæ, contains species of great agricultural importance as their caterpillars are the "cut-worms" or "surface caterpillars" which rank with "wireworms" and "leather jackets" as dreaded subterranean pests. The most important genus is Agrotis, which contains such familiar moths as the "dart" or turnip moth (*A. segetum*), and the "heart and dart" (*A. exclamationis*). The moths are mostly brown and inconspicuous, at all events when their hind wings are hidden, and fly to lamps at night. The caterpillars are earth-coloured fat grubs which feed for the most part underground but sometimes come up at night and attack the plant at the ground level or above it.

The Geometridæ are the moths with "looper" caterpillars and they include the well-known currant or "magpie" moth, and the "winter moths," which are among the most formidable of our orchard pests.

The common "winter moth" *Cheimatobia brumata*, appears in October and throughout the winter months. The wings of the female are only partially developed, and the insect cannot fly, but has to climb the trees to lay its eggs on the twigs, and the familiar "grease bands" are designed to catch the female on its way up the trunk. There are two larger species of similar habits but of later appearance.

The Tortricidæ or "leaf-roller" moths, of which the oak Tortrix is a familiar example, are small moths, generally of leaf-eating habits, but one species, *Cydia pomonella*, lives on the fruit of the apple, and is notorious as the "Codling moth."

Coleoptera. (Beetles). *Wings*—four, the front wings horny and not used in flight (elytra), the hind wings membranous and not greatly veined. In many species they are aborted.

Mouth-parts—biting.

Metamorphosis—complete.

The characteristic hard, shelly appearance of beetles is chiefly due to the elytra, which usually conceal the soft abdomen when closed, their edges meeting in a straight median line. Thus a dorsal view of the insect at rest shows only the head, the pro-thorax (which is always free) and the elytra, and no soft parts are visible. There are, of course, exceptions, and in one large family (the Staphylinidæ) the elytra are very short, leaving the abdomen exposed.

This immense order—nearly 180,000 species have been named and described—is markedly terrestrial, making no great show in the air, and often entirely lacking the power of flight. Economically it is very important, including a large number of agricultural pests, some of which are most injurious in the larval stage, others as fully developed beetles, while others again attack the roots of our crops as larvæ and do further harm to the leaves when adult. In so large an order there is necessarily a wide variety of habit, and there is a great difference in such matters as size, length of life, and the time spent as larva and as imago.

Metamorphosis is complete, all beetle eggs hatching out into some form of grub, but the larval forms are so various (on account of variety of habit) that it is not easy to say much that is true of them all. They all have a distinct head, with biting jaws. They are either legless or six-legged, having none of the sucker feet of the Lepidopterous caterpillars, though some beetle larvæ have a single prop at the hind end which acts much like a foot. If the student meets with a grub with a distinct biting head and with only six legs or none, he is fairly safe in concluding it to be the larva of some kind of beetle. Fortunately certain groups of beetles have larvæ of definite types which are easily recognized, so that it is often possible to identify the grub not only as that of a beetle, but that of a Carabid or a Lamellicorn or an Elaterid beetle or of a weevil and so on so that a reference to the pests known to attack the crop on which it is found will often afford a clue to the particular beetle in question.

The pupa is generally a white naked object with the legs and developing wings not covered in as in the Lepidopterous chrysalis. There is sometimes a cocoon, but more often the pupa is to be found in a smooth-walled cell in the ground. Its life ordinarily is quite short, and it quickly changes to the imago, which may remain quiescent for months before its time of activity arrives.

It is impossible to deal here with so large an order except in the most summary manner, but attention may be directed to a few groups easy of recognition both in the adult and larval condition.

Carnivorous insects are considered useful to the agriculturist as they often prey upon injurious species, and there are two familiar kinds of beetle which have this habit, the Carabidæ or "ground-beetles" and the Staphylinidæ or "rove" or "devil's coach horse" beetles.

The ground beetles are mostly nocturnal, but may be found in the day-time lurking under stones and boards. They are elegantly shaped and very active beetles, mostly black but sometimes blue or

metallic-hued, and their activity and build would suggest at once that they gain their livelihood by chasing prey. Some familiar species are quite large insects, but there is a great range of size in the group. They are not entirely blameless, for certain crops—especially strawberries—are occasionally attacked, but on the whole they are useful and should be spared. The rove beetles are easily recognized by their very short elytra, which leave the abdomen uncovered. They are either carnivorous or carrion feeding, and therefore not to be destroyed. The larvæ of both these families are active six-legged grubs with formidable jaws and generally rather well chitinized, often with cerci at the tail end. They are to be found in the soil where they hunt for prey and are very voracious.

The Lamellicorn beetles form a compact group easily recognized, and with a definite type of larva. The beetles are heavily built, oval insects, with antennæ terminating in leaves or *laminæ* which can be

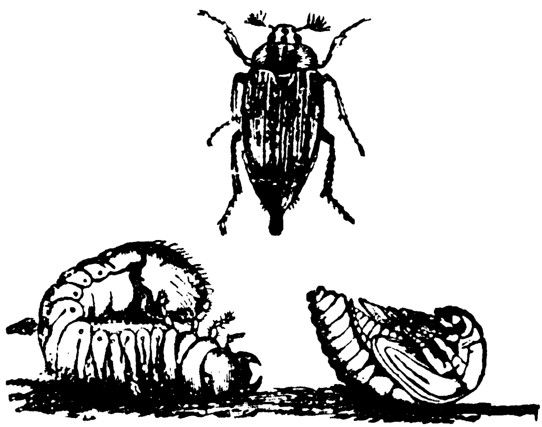

FIG. 125.—COCKCHAFER, *Melolontha vulgaris* (Coleoptera), with (A) larva and (B) pupa.

opened out or shut up. For practical purposes they are the stag, beetles, the dung-beetles and the chafers. The stag-beetles, which feed on decaying wood, are not important, nor are the dung-beetles, of which the Egyptian scarab and the British "Dor" beetle are examples, particularly objectionable, but the chafers are vegetable feeders and may be very destructive. The larvæ of Lamellicorn beetles are all of a pattern, and are what are generally known as "white grubs"—fleshy grubs of a whitish colour with strong brown heads and six legs and with curved bodies often thicker towards the hinder end (Fig. 125).

Chafers are destructive both as larvæ and as imagos, but quite different plants are generally attacked by the two stages. There are four common species in this country, the cockchafer (*Melolontha vulgaris*), the summer chafer (*Rhizotrogus solstilialis*), the rose chafer

(Cetonia aurata) and the garden chafer *(Phyllopertha horticola)*. All lay their eggs in the ground, and their grubs feed on roots—almost any root serving their turn. After a variable time spent as larvæ (four years in the case of the cockchafer) there is a very brief pupation period and the beetles emerge and fly away to trees or bushes to feed on the leaves. The cockchafer is particularly fond of oak leaves, and when its grub is found injuring the roots of a farm crop there is generally an oak wood in the neighbourhood.

The Elateridæ are the "skip-jack" or "click beetles," and some of them are the parents of the notorious "wireworms." The beetles, which are not very often met with are long and narrow, with convex backs and rather short legs. If placed on their backs on a smooth surface they have a difficulty in righting themselves without recourse to a special apparatus under the thorax which enables them to jump

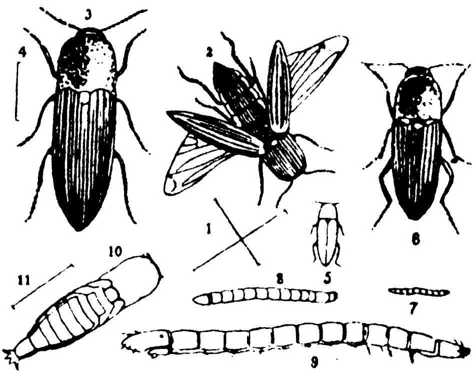

FIG. 126.—WIREWORMS AND CLICK BEETLES, *Elateridæ* (Coleoptera).
2, *Agriotes lineatus*, magnified ; 1, natural size.
3, *A. obscurus*, magnified ; 4, natural length.
5, *A. sputator*, natural size ; 6, magnified.
7, larva of *A. sputator* (?).
8, larva of *A. lineatus*, natural size ; 9, magnified.
10, pupa of wireworm, magnified ; 11, natural size.

quite a considerable height, when, with luck they alight on their feet and run away. Their larvæ are straw-coloured cylindrical grubs, well chitinized, with six short legs and a "prop" under the last segment of the abdomen, and the genus is Agriotes mainly responsible for the wireworms so hated by the farmer. The larval stage is very long—sometimes five or six years, and in this time the grub is able to do immense harm, especially as it destroys very much more than it devours, attacking germinating seeds, or biting off a plant at the ground level (Fig. 126).

Freshly ploughed up grass-land is sure to be full of wireworm, and a corn crop sown on it has little chance of success. It is usual to take at first such a crop as potatoes, which afford some chance of a fair yield, while the cultural operations possible in a potato field help to clear the ground of the grubs by turning them up to the birds.

Many agricultural pests belong to a miscellaneous group of beetles (Chrysomelidæ, Halticidæ, etc.), commonly known as " plant beetles." The Colorado potato beetle, the mustard beetle and the asparagus beetle, are examples. Eggs, larvæ, pupæ and imagos may often be found simultaneously on the same plant, and the larvæ are fleshy grubs with distinct heads and six legs. The " turnip-fly " is a minute Halticid beetle (" flea beetle "). These beetles have their hind thighs thickened and possess considerable powers of jumping. Several species are generally present in a turnip-fly attack, though the name was first given to one species, *Phyllotreta nemorum*. Every farmer knows the havoc that may be wrought on the cotyledons of newly germinated turnip seeds by these beetles. The whole crop may be destroyed unless immediate measures are taken against it. It is a dry weather pest (Fig. 127).

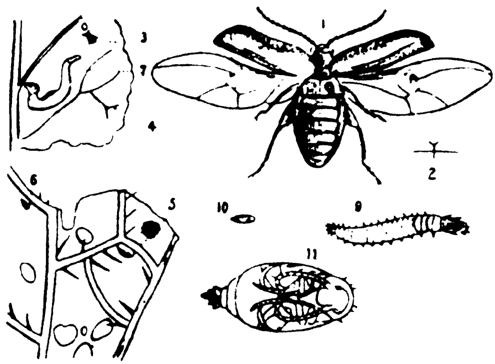

FIG. 127.—TURNIP FLY. *Phyllotreta* (*Haltica*) *nemorum* (Coleoptera).
1, mature beetle, magnified ; 2, 3, natural size.
4, 5, eggs laid on under surface of rough leaf.
6, 7, burrows in leaf, made by larvæ or maggots.
8, larva, natural size ; 9, magnified.
10, pupa, natural size ; 11, magnified.

Weevils (Curculionidæ) are beetles with their heads produced into a beak which carries the biting jaws at the end. Their larvæ are legless white grubs, generally found in the soil, feeding on the roots of crops, though some have different habits. The imagos are generally injurious, and to some special part of the plant. Sitona weevils attack the leaves of leguminous crops, scalloping the edges. Otiorrhynchus weevils nibble the stems and petioles of vines and strawberries. Anthonomus weevils attack the flower buds of apple, etc., and Apion weevils the inflorescences of clover and sainfoin, while weevils of the genus Balaninus attack fruits, such as nuts and acorns.

Two other groups of beetles may be briefly mentioned. Longicorn beetles (Cerambycidæ), characterized by particularly long antennæ, have cylindrical, generally legless larvæ with the segments behind the

head often enlarged, and they are wood feeders, boring tunnels of oval section in the trunks of trees.

Ladybird beetles (*Coccinelidæ*) are extremely useful, feeding both as larvæ and imagos on Rhynchota, and being among the most voracious destroyers of aphis and scale insects.

HYMENOPTERA.

Wings—four, the hind wings small and hooked on to the fore wings.

Mouth-parts—biting.

Metamorphosis—complete.

Familiar examples of Hymenoptera are sawflies, bees, wasps, ants, ichneumon flies and gall wasps. The females always have ovipositors which in some groups are modified into stings. Insects of this order are mandibulate, but the mandibles are more often used for nest construction, etc., than for feeding, and the labium is frequently produced into a sucking tongue. Two divisions of the order are recognised:—Sessiliventres (Symphyta) and Petiolata (Apocrita).

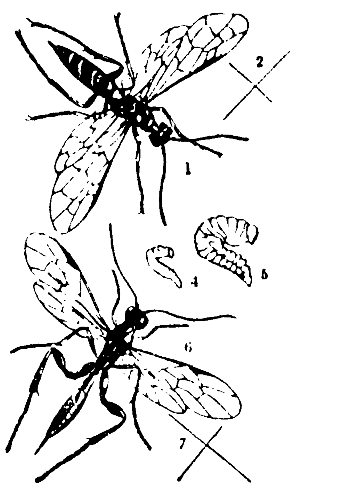

FIG. 128.—CORN SAWFLY, *Cephus pygmæus* (Hymenoptera).
1. female fly ; 2, natural size.
3, corn-stem, containing maggot.
4, larva or maggot, natural size ; 5, magnified.
6, parasitic ichneumon fly, *Pachymerus calcitrator*, magnified ; 7, natural size.

The Sessiliventres are the sawflies. The abdomen is not stalked (petiolate) but is joined broadly to the thorax, and the ovipositor of the female is furnished with a pair of saws for cutting holes in plant tissues for the deposition of eggs.

Stem sawflies (Cephidæ) and wood-wasps (Siricidæ) have larvæ which are practically legless, since these larvæ feed within plant tissues. The larva of *Cephus pygmæus* is found in the stems of cereals and grasses, and may do considerable harm to a wheat crop. The wood-wasps are striking insects of formidable appearance, *Sirex gigas* often being mistaken for a hornet. They lay their eggs in the trunks of trees, within which their larvæ feed. Most of the sawflies of agricultural importance belong to the family Tenthredinidæ. The imagos are generally small inconspicuous insects, recognised by the possession of four wings, thick waists and short antennæ. Their larvæ are free-living, generally feeding on the leaves of plants, and behaving precisely like Lepidopterous caterpillars, which they greatly resemble in

appearance, being furnished with "sucker feet" in addition to three pairs of jointed legs on the thoracic segments. They may be most readily distinguished from Lepidopterous caterpillars by the fact that while these have at most five pairs of sucker feet Tenthredinid larvæ have more—either six, seven or eight pairs of such feet. Other distinguishing points are that there is a single eye-spot on the head, instead of a scattered group of eyes, and that the sucker-feet do not terminate in hooks. Pine sawfly and gooseberry sawfly are familiar examples. The larvæ or "false caterpillars" defoliate the plants, and are dealt with in the same way as with true caterpillars. Some, however, feed on fruit, and apples and plums may often be found to contain the larvæ of Tenthredinid sawflies.

The Petiolata have a constriction between the thorax and the

FIG. 129.—HUMBLE BEES, *Bombus* sp. (Hymenoptera).
1, wood bee, *Bombus lecorum*.
2, 3, punctures in calyx of bean flower, through which nectar is withdrawn.
4, earth bee, *Bombus terrestris*.

abdomen. They may be conveniently divided into the Aculeata and the Parasitica.

The Aculeata are the "stingers"—the bees, wasps and ants. In their case the ovipositor is modified into a weapon of offence, accompanied by a poison gland. Many other insects inflict punctures on animals—mosquitoes for instance—but in their case the mouth apparatus is employed. The Parasitica have a piercing ovipositor, but it is still employed for depositing eggs, and not as an offensive weapon. The most familiar of the Aculeata have social habits, living in communities, often with considerable division of labour among the members of the community, but others are solitary (Fig. 129).

The bees, apart from the commodities with which the hive bee furnishes us (honey and wax), are of great utility in cross-fertilizing flowers, and some of our crops—clover for example—are dependent on them for this service. Social wasps are useful in another way. Though we dislike their sting and their depredations on ripe fruit, it should be remembered in their favour that they rear their young on

insects and in so doing destroy vast numbers of insect pests, especially Diptera. To exterminate them would be a great mistake, but a reduction of their numbers is often desirable. This is best effected by destroying all wasps found in the winter months, for only the queens survive the winter, and any wasp found at that season is the potential founder of a nest for the following summer.

The ants are of no great agricultural importance, though their habits are of extreme interest.

The Parasitica use their piercing ovipositors for inserting their eggs either into animals or plants, in whose tissues their larvæ live. For practical purposes they are the ichneumon flies in the broad sense (Ichneumonidæ, Chalcidæ, Proctotrypidæ, Braconidæ) and the Gall wasps (Cynipidæ).

Ichneumon flies are of supreme importance in the natural control of insect pests, and but for their assistance our crops would be at the mercy of hosts of destructive insects. Each ichneumon fly seeks out

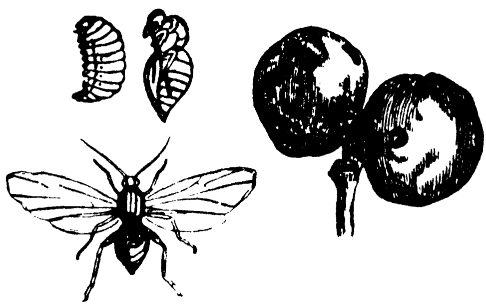

FIG. 130.—MARBLE-GALL FLY, *Cynips kollari* (Hymenoptera).
Larva, pupa, and mature insect, magnified.
Galls ("oak apples") of oak tree.

its special victim, into some stage of which—egg, larva, pupa or imago—it inserts its eggs, which hatch out into grubs which eventually destroy the insect attacked. Some species are so small that an insect's egg supplies sufficient nourishment for the development of the parasite. Probably the larval stage is most often attacked. A familiar example is afforded by the cabbage caterpillar of the large white butterfly which may often be seen surrounded by a cluster of yellow cocoons, commonly, but absurdly, called "caterpillar's eggs." What has happened is that a small ichneumon fly (*Apanteles glomeratus*) laid eggs in the caterpillar and its grubs, after eating out the internal organs, have pupated in yellow cocoons on the outside of the hollow skin. Each cocoon will give rise to an ichneumon capable of destroying more caterpillars. Very often the parasitized caterpillar is just able to turn to a chrysalis before its final destruction.

Anyone who has had experience in rearing insects is familiar with the fact that a certain number always prove to be "ichneumon-stung," and give rise to ichneumon flies instead of the proper image. With some pests a certain cycle is often observed, the trouble

suddenly appearing, increasing for a few years, and then as suddenly disappearing. The disappearance is frequently found to be due to the great increase of parasitism by ichneumon flies, so that the pest is for the time being almost exterminated and may be quite rare the following season. A good example may be seen in the oak tortrix, which in bad years defoliates the oak trees in summer.

The Gall wasps (Cynipidæ) are injurious, but not often to an important degree. Galls are swellings in the tissues of plants, made by the plants in response to some irritation, such as the insertion of an egg together with some irritant fluid, or the movements of the grub which hatches out. A certain amount of the vitality of the plant is diverted into forming tissues of no use to it, and the result may be a stunting and loss of condition. A great many different creatures—flies, aphids, mites, etc.—may cause galls, but many of the most familiar galls such as "oak apples" and "marble galls," and the moss gall on the wild rose, are due to the Cynipidæ of the Hymenoptera (Fig. 130).

DIPTERA.

Wings—two only.
Mouth-parts—sucking, sometimes piercing and sucking
Metamorphosis—complete.

The Diptera are the true flies, having only one pair of wings, though they possess traces of a second pair in the form of the ***halteres*** or balancers behind the existing pair. The head is generally very mobile, and the compound eyes very large. Most flies suck or mop up fluids with a proboscis formed from the labium, but some (*e.g.*, mosquitoes) possess a piercing apparatus which enables them to reach the blood of animals which they then obtain by suction. The thorax is always fused, the three segments not being distinguishable.

Dipterous larvæ never have any true legs, though many of them are able to progress quite actively by means of bristles, hooks or pimple-like excrescences of the body. As a general rule they are legless, headless maggots, but flies whose early life is passed in water, like the mosquito, may have completely developed heads. They are nearly always devoid of colour markings.

Many flies superficially resemble members of the Hymenoptera (bees and wasps) and a close scrutiny is often necessary to determine whether only two wings are present or whether there are in reality two wings on each side securely hooked together.

The two main divisions of the Diptera are the ORTHORRHAPHA and the CYCLORRHAPHA, the names having reference to the nature of the pupæ.

Orthorrhapha.

These are flies with the antennæ either long (Nematocera) or short (Brachycera) projecting forward from the head and many-jointed. On pupation the last larval skin is not retained and the pupal skin is split down the back when the imago emerges. Many of the

Orthorrhapha are blood-suckers (mosquitoes, sand-flies, midges, gad-flies, etc.) and of great importance as disease carriers, especially in tropical countries. Two families are of agricultural importance, the Tipulidæ or crane-flies and the Cecidomyidæ or gall midges. The Tipulidæ are the crane-flies or "daddy long legs," and their brownish, tough-skinned grubs are the "leather-jackets" so destructive at the roots of grass and other plants. Golf greens often suffer severely, and crops sown on broken up grass-land are frequently destroyed by this pest (Fig. 131). The Cecidomyidæ are minute gnat-like flies with white or orange-coloured maggots which are often provided with an "anchor-process" beneath the front end of the body and have the power of jumping like the familiar cheese maggot. They include several well-known agricultural pests such as the Hessian fly and the wheat-midge, clover-midge, pea-midge, pear-midge, etc., and are also responsible for very many of the galls which disfigure the leaves and shoots of various trees.

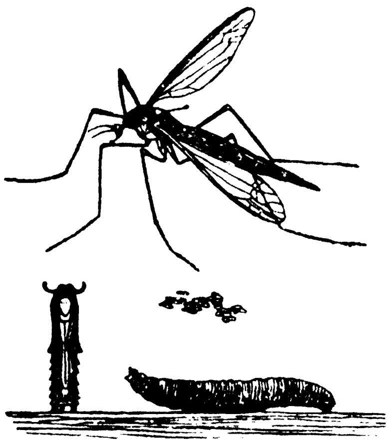

FIG. 131.—DADDY LONGLEGS, *Tipula oleracea* (Diptera), with eggs, grub (leather jacket), and pupa.

Cyclorrhapha.

The bulk of the flies belong to this division. Their antenna is characteristic, consisting of three joints, not projecting forward, but hanging down, while from the large third joint a stout bristle—the *arista*—arises. The maggots or "gentles" of the blow-fly are typical of their larvæ, which are headless and legless grubs, generally tapering, the narrow end being the anterior, and the truncated posterior end showing a pair of conspicuous spiracles, and generally some protuberances characteristic of the species. The mouth apparatus consists of a pair of chitinous hooks which can be exserted or withdrawn, and with which the maggots tear the tissues on which they feed.

When the larva is about to pupate it does not shed its skin, but this shrinks and hardens to form a brown or chestnut-coloured "fly-case" or *puparium*, within which the true pupa is formed. This does not split longitudinally for the emergence of the fly but the anterior end is removed by a circular cut—hence cyclorrhapha.

Many of our crops are attacked by maggots of the type here

described. Familiar examples are frit-fly in oats, wheat-bulb fly, onion-fly, carrot-fly, celery-fly, mangold-fly and root maggot-fly (Fig. 132).

The maggots of certain flies attack domestic animals. Flies of the blow-fly group, which are normally scavengers, laying their eggs in dead bodies, are attracted to tainted sores in the fleece of sheep and their grubs often invade the surrounding flesh, doing great injury. One family of flies, the Œstridæ or "bot-flies" pass their larval period entirely in the tissues or natural cavities of animals, and in this country the horse, the sheep and the ox are all subject to such infestations. The horse bot-fly (*Gastrophilus intestinalis*) attaches eggs to the hairs of the horse and the maggots which hatch out are

FIG. 132.—WHEAT-BULB FLY, *Hylemyia coarctata* (Diptera).

1, mouth apparatus. 1a, maggot. 2, extremity of tail.
3, pupa. 4, mature fly. 5, infested wheat plant.
1a, 3, and 4, natural size and magnified. 1 and 2, magnified.

licked off by the animal and reach the stomach where they remain for months, attached to the wall by their mouth hooks, eventually emerging by the anus, and quickly changing to puparia and imagos. The sheep bot-fly or nose-fly oviposits in the nostrils of sheep during rumination, and the maggots live for months in the nasal cavities and cause great distress and loss of condition.

The most important of the Œstridæ are the ox bot-flies or "warble flies" of cattle. In March, small swellings or "warbles" are noticed in the hides of cattle on either side of the back bone. These swellings contain maggots which presently pierce an opening to the exterior. To this opening they apply their posterior spiracles and thenceforward grow rapidly. When fully grown they emerge through this aperture and hide away in the ground, quickly turning to puparia and flies. How these grubs reached their position in the hide was a problem which long baffled all investigators, but it has now been

solved and a very remarkable life history revealed. The flies live a very short time, being quite incapable of feeding. The female attaches eggs to the hairs, generally on the legs of cattle, during bright sunny weather, and if the animals become aware of the fly they show great alarm, and "gad." The minute maggot which hatches out bores into the animal at the spot where the egg is laid, and all the larval existence is passed in the tissues of the animal, the hide of the back being eventually entered not from the outside, but from below. The most obvious harm done is to the hides, a large proportion of which are ruined from the tanners' point of view, but infested cattle lose condition, have their output of milk reduced, and a certain amount of their flesh made unsaleable ("licked beef") by the ravages of the maggots. There are two species of the fly—*Hypoderma bovis* and *H. lineatum*, but their behaviour is much alike. *H. lineatum* is the earlier fly, and lays several eggs on the same hair. *H. bovis* appears about a month later and attaches a single egg to the base of each hair. The flies are very bee-like in appearance.

Attempts to prevent the fly from ovipositing on cattle have not proved successful, but it is possible to kill the maggots in the backs of cattle by squeezing out or by the application of dressings, and if this method were extensively carried out there would be few flies to carry on the attack in the following season.

Hover-flies (Syrphidæ) were mentioned among the insects which prey upon aphis. The common species are rather wasp-like flies, often banded with yellow, and they may be noticed hovering over rose and other bushes in the summer. They are searching for aphidæ, among which they lay their eggs, and their semi-transparent maggots feed greedily upon these troublesome pests.

Wingless members of the Diptera are not very common, but one, the sheep "ked" (*Melophagus ovinus*) is only too familiar. It is often wrongly called the sheep tick, but this is an error, for ticks are Arachnida and eight-legged when adult, whereas the "ked" is six-legged and is a fly without wings. It has a near relation in the "forest-fly" so troublesome to horses in the New Forest, and this species is winged. These flies belong to a group known as Pupipara because the whole development of the larva takes place within the fly and the puparium is deposited. In the fleece of the sheep both the flies and their puparia may be found. The flies are blood-suckers, and it is chiefly on account of these and also the true ticks that sheep are "dipped."

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